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THE RADIOMETER: A FRESH EVIDENCE OF A MOLECULAR UNIVERSE.[1]

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NO one who is not familiar with the history of physical science can appreciate how very modern are those grand conceptions which add so much to the loftiness of scientific studies; and of the many who, on one of our starlit nights, look up into the depths of space, and are awed by the thoughts of that immensity which come crowding upon the mind, there are few, I imagine, who realize the fact that almost all the knowledge, which gives such great sublimity to that sight, is the result of comparatively recent scientific investigation; and that the most elementary student can now gain conceptions of the immensity of the universe of which the fathers of astronomy never dreamed. And how very grand are the familiar astronomical facts which the sight of the starry heavens suggests!

Those brilliant points are all suns like the one which forms the centre of our system, and around which our earth revolves; yet so inconceivably remote, that although moving through space with an incredible velocity they have not materially changed their relative position since recorded observations began. Compared with their distance, the distance of our own sun—92,000,000 miles—seems as nothing; yet how inconceivable even that distance is when we endeavor to mete it out with our terrestrial standards! For, if, when Copernicus—the great father of modern astronomy—died, in 1543, just at the close of the Protestant Reformation, a messenger had started for the sun, and traveled ever since with the velocity of a railroad-train—thirty miles an hour—he would not yet have reached his destination!

[1] A lecture delivered in the Sanders Theatre of Harvard University, March 6, 1878.

Evidently, then, no standards, which like our ordinary measures bear a simple or at least a conceivable relation to the dimensions of our own bodies, can help us to stretch a line in such a universe. We must seek for some magnitude which is commensurate with these immensities of space; and, in the wonderfully rapid motion of light, astronomy furnishes us with a suitable standard. By the eclipses of Jupiter's satellites the astronomers have determined that this mysterious effluence reaches us from the sun in eight minutes and a half, and therefore must travel through space with the incredible velocity—shall I dare to name it—of 186,000 miles in a second of time! Yet inconceivably rapid as this motion is, capable of girdling the earth nearly eight times in a single second, the very nearest of the fixed stars, *a* Centauri, is so remote that the light by which it will be seen in the southern heavens to-night, near that magnificent constellation the Southern Cross, must have started on its journey three years and a half ago. But this light comes from merely the threshold of the stellar universe; and the telescope reveals to us stars so distant that, had they been blotted out of existence when history began, the tidings of the event could not yet have reached the earth!

Compare now with these grand conceptions the popular belief of only a few centuries back. Where we look into the infinite depths, our Puritan forefathers saw only a solid dome hemming in the earth and skies, and through whose opened doors the rain descended. They regarded the sun and moon merely as great luminaries set in this firmament to rule the day and night, and to their understandings the stars served no better purpose than the spangles which glitter on the azure ceiling of many a modern church. The great work of Copernicus, "De Orbium Cœlestium Revolutionibus," which was destined, ultimately, to overthrow the crude cosmography which Christianity had inherited from Judaism, was not published until just at the close of the author's life in 1543, the date before mentioned. The telescope, which was required to fully convince the world of its previous error, was not invented until more than half a century later, and it was not until 1835 that Struve detected the parallax of *a* Lyræ. The measurement of this parallax, together with Bessel's determination of the parallax of 61 Cygni, and Henderson's that of *a* Centauri, at about the same time, gave us our first accurate knowledge of the distances of the fixed stars.

To the thought I have endeavored to express I must add another, before I can draw the lesson which I wish to teach. Great scientific truths become popularized very slowly, and, after they have been thoroughly worked out by the investigators, it is often many years before they become a part of the current knowledge of mankind. It was fully a century after Copernicus died, with his great volume—still wet from the press of Nuremburg—in his hands, before the Copernican theory was generally accepted even by the learned; and the intolerant spirit with which this work was received, and the persecution which

Galileo encountered more than half a century later, were due solely to the circumstance that the new theory tended to subvert the popular faith in the cosmography of the Church. In modern times, with the many popular expositors of science, the diffusion of new truth is more rapid; but even now there is always a long interval after any great discovery in abstract science before the new conception is translated into the language of common life, so that it can be apprehended by the mass even of educated men.

I have thus dwelt on what must be familiar facts in the past history of astronomy, because they illustrate and will help you to realize the present condition of a much younger branch of physical science: for in the transition-period I have described there exists now a conception which opens a vision into the microcosmos beneath us as extensive and as grand as that which the Copernican theory revealed into the macrocosmos above us.

The conception to which I refer will be at once suggested to every scientific scholar by the word *molecule*. This word is a Latin diminutive, which means, primarily, a small mass of matter; and although heretofore often applied in mechanics to the indefinitely small particles of a body between which the attractive or repulsive forces might be supposed to act, it has only recently acquired the exact significance with which we now use it.

In attempting to discover the original usage of the word molecule, I was surprised to find that it was apparently first introduced into science by the great French naturalist, Buffon, who employed the term in a very peculiar sense. Buffon does not seem to have been troubled with the problem which so engrosses our modern naturalists—how the vegetable and animal kingdoms were developed into their present condition—but he was greatly exercised by an equally difficult problem, which seems to have been lost sight of in the present controversy, and which is just as obscure to-day as it was in Buffon's time, at the close of the last century, and that is, Why species are so persistent in Nature; why the acorn *always* grows into the oak, and why every creature *always* produces of its kind. And, if you will reflect upon it, I am sure you will conclude that this last is by far the more fundamental problem of the two, and one which necessarily includes the first. That of two eggs, in which no anatomist can discover any structural difference, the one should, in a few short years, *develop* an intelligence like Newton's, while the other soon ends in a Guinea-pig, is certainly a greater mystery than that, in the course of unnumbered ages, monkeys, by insensible gradations, should *grow* into men.

In order to explain the remarkable constancy of species, Buffon advanced a theory which, when freed from a good deal that was fanciful, may be expressed thus: The attributes of every species, whether of plants or of animals, reside in their ultimate particles, or, to use a more philosophical but less familiar word, *inhere* in these particles, which

Buffon names *organic molecules.* According to Buffon, the oak owes all the peculiarities of its organization to the special oak-molecules of which it consists; and so all the differences in the vegetable or animal kingdom, from the lowest to the highest species, depend on fundamental peculiarities with which their respective molecules were primarily endowed. There must, of course, be as many kinds of molecules as there are different species of living beings; but, while the molecules of the same species were supposed to be exactly alike and to have a strong affinity or attraction for each other, those of different species were assumed to be inherently distinct and to have no such affinities. Buffon further assumed that these molecules of organic Nature were diffused more or less widely through the atmosphere and through the soil, and that the acorn grew to the oak simply because, consisting itself of oak-molecules, it could draw only oak-molecules from the surrounding media.

With our present knowledge of the chemical constitution of organic beings, we can find a great deal that is both fantastic and absurd in this theory of Buffon, but it must be remembered that the science of chemistry is almost wholly a growth of the present century, while Buffon died in 1788; and, if we look at the theory solely from the standpoint of his knowledge, we shall find in it much that was worthy of this great man. Indeed, in our time the essential features of the theory of Buffon have been transferred from natural history to chemistry almost unchanged.

According to our modern chemistry, the qualities of every substance reside or inhere in its molecules. Take this lump of sugar. It has certain qualities with which every one is familiar. Are those qualities attributes of the lump or of its parts? Certainly of its parts. For, if we break up the lump, the smallest particles will still taste sweet and show all the characteristics of sugar. Could we then carry on this subdivision indefinitely provided only we had senses or tests delicate enough to recognize the qualities of sugar in the resulting particles? To this question, modern chemistry answers decidedly: No! You would before long reach the smallest mass that can have the qualities of sugar. You would have no difficulty in breaking up these masses, but you would then obtain not smaller particles of sugar, but particles of those utterly different substances which we call carbon, oxygen, and hydrogen, in a word particles of the elementary substances of which sugar consists. These ultimate particles of sugar we call the molecules of sugar, and thus we come to the present chemical definition of a molecule, "*The smallest particles of a substance in which its qualities inhere,*" which, as you see, is a reproduction of Buffon's idea, although applied to matter and not to organism.

A lump of sugar, then, has its peculiar qualities because it is an aggregate of molecules which have those qualities, and a lump of salt differs from a lump of sugar simply because the molecules of salt differ

from those of sugar, and so with every other substance. There are as many kinds of molecules in Nature as there are different substances, but all the molecules of the same substance are absolutely alike in every respect.

Thus far, as you see, we are merely reviving in a different association the old ideas of Buffon. But just at this point comes in a new conception, which gives far greater grandeur to our modern theory: for we conceive that those smallest particles in which the qualities of a substance inhere are definite bodies or systems of bodies moving in space, and that *a lump of sugar is a universe of moving worlds.*

If on a clear night you direct a telescope to one of the many star-clusters of our northern heavens, you will have presented to the eye as good a diagram as we can at present draw of what we suppose would, under certain circumstances, be seen in a lump of sugar if we could look into the molecular universe with the same facility with which the telescope penetrates the depths of space. Do you tell me that the absurdities of Buffon were wisdom when compared with such wild speculations as these? The criticism is simply what I expected, and I must remind you that, as I intimated at the outset, this conception of modern science is in the transition period of which I then spoke, and, although very familiar to scientific scholars, has not yet been grasped by the popular mind. I can, further, only add that, wild as it may appear, the idea is the growth of legitimate scientific investigation, and express my conviction that it will soon become as much a part of the popular belief as those grand conceptions of astronomy to which I have referred. Do you rejoin that we can see the suns in a stellar cluster, but cannot even begin to see the molecules? I must again remind you that, in fact, you only see points of light in the field of the telescope, and that your knowledge that these points are immensely distant suns is an inference of astronomical science; and further that our knowledge—if I may so call our confident belief—that the lump of sugar is an aggregate of moving molecules is an equally legitimate inference of molecular mechanics, a science which, although so much newer, is as positive a field of study as astronomy. Moreover, sight is not the only avenue to knowledge; and, although our material limitations forbid us to expect that the microscope will ever be able to penetrate the molecular universe, yet we feel assured that we have been able by strictly experimental methods to weigh molecular masses, and measure molecular magnitudes, with as much accuracy as those of the fixed stars.

Of all forms of matter the gas has the simplest molecular structure, and, as might be anticipated, our knowledge of molecular magnitudes is as yet chiefly confined to materials of this class. I have given below some of the results which have been obtained in regard to the molecular magnitudes of hydrogen gas, one of the best studied of this class of substances; and, although the vast numbers are as inconceivable as are those of astronomy, they cannot fail to impress you with the reality of

the magnitudes they represent. I take hydrogen gas for my illustration rather than air, because our atmosphere is a mixture of two gases, oxygen and nitrogen, and therefore its condition is less simple than that of a perfectly homogeneous material like hydrogen. The molecular dimensions of other substances, although varying very greatly in their relative values, are of the same order as these.[1]

Dimensions of Hydrogen Molecules calculated for Temperature of Melting Ice and for the Mean Height of the Barometer at the Sea-Level.

Mean velocity, 6,099 feet a second.
Mean path, 31 ten-millionths of an inch.
Collisions, 17,750 millions each second.
Diameter, 438,000, side by side, measure $\frac{1}{100}$ of an inch.
Mass, 14 (millions[3]) weigh $\frac{1}{1000}$ of a grain.
Gas-volume, 311 (millions[3]) fill one cubic inch.

To explain how the values here presented were obtained would be out of place in a popular lecture,[2] but a few words in regard to two or three of the data are required to elucidate the subject of this lecture.

First, then, in regard to the mass or weight of the molecules. So far as their relative values are concerned, chemistry gives us the means of determining the molecular weights with very great accuracy; but when we attempt to estimate their weights in fractions of a grain—the smallest of our common standards—we cannot expect precision, simply because the magnitudes compared are of such a different order; and the same is true of most of the other absolute dimensions, such as the diameter and volume of the molecules. We only regard the values given in our table as a very rough estimate, but still we have good

[1] As some of the readers of this journal may be interested to compare these values, we reproduce the "Table of Molecular Data" from Prof. Clerk Maxwell's lecture on "Molecules," delivered before the British Association at Bradford, and published in *Nature*, September 25, 1873.

Molecular Magnitudes at Standard Temperature and Pressure, 0° C. and 76 c. m.

RANK ACCORDING TO ACCURACY OF KNOWLEDGE.	Hydrogen.	Oxygen.	Carbonic Oxide.	Carbonic Dioxide.
RANK I.				
Relative mass	1	16	14	22
Velocity in metres per second	1,859	465	497	396
RANK II.				
Mean path in ten billionths ($_{10}{}^{-10}$) of a metre	965	560	482	379
Collisions each second—number of millions	17,750	7,646	9,489	9,720
RANK III.				
Diameter in hundred billionths ($_{10}{}^{-11}$) of a metre	58	76	83	93
Mass in ten million million million millionths ($_{10}{}^{-36}$) of a gramme	46	736	644	1,012

Number of molecules in one cubic centimetre of every gas is nineteen million million million on 19 ($_{10}{}^{18}$).

Two million hydrogen molecules side by side measure a little over one millimetre.

[2] *See* Prof. Maxwell's lecture, *loc. cit.*; also Appletons' "Cyclopædia," article "Molecules."

grounds for believing that they are sufficiently accurate to give us a true idea of the order of the quantities with which we are dealing; and it will be seen that although the numbers required to express the relations to our ordinary standards are so large, these molecular magnitudes are no more removed from us on the one side than are those of astronomy on the other.

Passing next to the velocity of the molecular motion, we find in that a quantity which, although large, is commensurate with the velocity of sound, the velocity of a rifle-ball, and the velocities of many other motions with which we are familiar. We are, therefore, not comparing, as before, quantities of an utterly different order, and we have confidence that we have been able to determine the value within very narrow limits of error. But how surprising the result is! Those molecules of hydrogen are constantly moving to and fro with this great velocity, and not only are the molecules of all aëriform substances moving at similar, although differing, rates, but the same is equally true of the molecules of every substance, whatever may be its state of aggregation.

The gas is the simplest molecular condition of matter, because in this state the molecules are so far separated from each other that their motions are not influenced by mutual attractions. Hence, in accordance with the well-known laws of motion, gas-molecules must always move in straight lines and with a constant velocity until they collide with each other or strike against the walls of the containing vessel, when, in consequence of their elasticity, they at once rebound and start on a new path with a new velocity. In these collisions, however, there is no loss of motion, for, as the molecules have the same weight, and are perfectly elastic, they simply change velocities, and whatever one may lose the other must gain.

But if the velocity changes in this way, you may ask, What meaning has the definite value given in our table? The answer is, that this is the mean value of the velocity of all the molecules in a mass of hydrogen gas under the assumed conditions; and, by the principle just stated, the mean value cannot be changed by the collisions of the molecules among themselves, however great may be the change in the motion of the individuals.

In both liquids and solids the molecular motions are undoubtedly as active as in a gas, but they must be greatly influenced by the mutual attractions which hold the particles together, and hence the conditions are far more complicated, and present a problem which we have been able to solve only very imperfectly, and with which, fortunately, we have not at present to deal.

Limiting, then, our study to the molecular condition of a gas, picture to yourselves what must be the condition of our atmosphere, with its molecules flying about in all directions. Conceive what a molecular storm must be, raging about us, and how it must beat against our bodies and against every exposed surface. The molecules of our

atmosphere move, on an average, nearly four (3.8) times slower than those of hydrogen under the same conditions; but then they weigh, on an average, fourteen and a half times more than hydrogen-molecules, and therefore strike with as great energy. And do not think that the effect of these blows is insignificant because the molecular projectiles are so small; they make up by their number for what they want in size.

Consider, for example, a cubic yard of air, which, if measured at the freezing-point, weighs considerably over two pounds. That cubic yard of material contains over two pounds of molecules, which are moving with an average velocity of 1,605 feet a second, and this motion is equivalent, in every respect, to that of a cannon-ball of equal weight, rushing along its path at the same tremendous rate. Of course, this is true of every cubic yard of air at the same temperature; and, if the motion of the molecules of the atmosphere around us could by any means be turned into one and the same direction, the result would be a hurricane sweeping over the earth with this velocity—that is, at the rate of 1,094 miles an hour—whose destructive violence not even the Pyramids could withstand.

Living as we do in the midst of a molecular tornado capable of such effects, our safety lies wholly in the circumstance that the storm beats equally in all directions at the same time, and the force is thus so exactly balanced that we are wholly unconscious of the tumult. Not even the aspen-leaf is stirred, nor the most delicate membrane broken; but let us remove the air from one of the surfaces of such a membrane, and then the power of the molecular storm becomes evident, as in the familiar experiments with an air-pump.

As has already been intimated, the values of the velocities both of hydrogen and of air molecules given above were measured at a definite temperature, 32° of our Fahrenheit thermometer, the freezing-point of water; and this introduces a very important point bearing on our subject, namely, that the molecular velocities vary very greatly with the temperature. Indeed, according to our theory, this very molecular motion constitutes that state or condition of matter which we call temperature. A hot body is one whose molecules are moving comparatively rapidly, and a cold body one in which they are moving comparatively slowly. Without, however, entering into further details, which would involve the whole mechanical theory of heat, let me call your attention to a single consequence of the principle I have stated.

When we heat hydrogen, air, or any mass of gas, we simply increase the velocity of its moving molecules. When we cool the gas, we simply lessen the velocity of the same molecules. Take a current of air which enters a room through a furnace. In passing it comes in contact with heated iron, and, as we say, is heated. But, as we view the process, the molecules of the air, while in contact with the hot iron, collide with the very rapidly-oscillating metallic molecules, and fly back as a billiard-ball would under similar circumstances, with a greatly-in-

creased velocity, and it is this more rapid motion which alone constitutes the higher temperature.

Consider, next, what must be the effect on the surface. A moment's reflection will show that the normal pressure exerted by the molecular storm, always raging in the atmosphere, is due not only to the impact of the molecules, but also to the reaction caused by their rebound. When the molecules rebound they are, as it were, driven away from the surface in virtue of the inherent elasticity both of the surface and of the molecules. Now, what takes place when one mass of matter is driven away from another—when a cannon-ball is driven out of a gun, for example? Why, the gun *kicks!* And so every surface from which molecules rebound must *kick;* and, if the velocity is not changed by the collision, one-half of the pressure caused by the molecular bombardment is due to the recoil. From a heated surface, as we have said, the molecules rebound with an increased velocity, and hence the recoil must be proportionally increased, determining a greater pressure against the surface.

According to this theory, then, we should expect that the air would press unequally against surfaces at different temperatures, and that, other things being equal, the pressure exerted would be greater the higher the temperature of the surface. Such a result, of course, is wholly contrary to common experience, which tells us that a uniform mass of air presses equally in all directions and against all surfaces of the same area, whatever may be their condition. It would seem, then, at first sight, as if we had here met with a conspicuous case in which our theory fails. But further study will convince us that the result is just what we should expect in a dense atmosphere like that in which we dwell; and, in order that this may become evident, let me next call your attention to another class of molecular magnitudes.

It must seem strange indeed that we should be able to measure molecular velocities, but the next point I have to bring to your notice is stranger yet, for we are confident that we have been able to determine with approximate accuracy for each kind of gas-molecule the average number of times one of these little bodies runs against its neighbors in a second, assuming, of course, that the conditions of the gas are given. Knowing, now, the molecular velocity and the number of collisions a second, we can readily calculate the mean path of the molecule—that is, the average distance it moves, under the same conditions, between two successive collisions. Of course, for any one molecule, this path must be constantly varying; since, while at one time the molecule may find a clear coast and make a long run, the very next time it may hardly start before its course is arrested. Still, taking a mass of gas under constant conditions, the doctrine of averages shows that the mean path must have a definite value, and an illustration will give an idea of the manner in which we have been able to estimate it.

The nauseous smelling gas we call sulphide of hydrogen has a density only a little greater than that of air, and its molecules must therefore move with very nearly as great velocity as the average air-molecule—that is to say, about 1,480 feet a second; and we might therefore expect that, on opening a jar of the gas, its molecules would spread instantly through the surrounding atmosphere. But so far from this, if the air is quiet, so that the gas is not transported by currents, a very considerable time will elapse before the characteristic odor is perceived on the opposite side of an ordinary room. The reason is obvious—the molecules must elbow their way through the crowd of air-molecules which already occupy the space, and can therefore advance only slowly; and it is obvious that, the oftener they come into collision with their neighbors, the slower their progress must be. Knowing, then, the mean velocity of the molecular motion, and being able to measure by appropriate means *the rate of diffusion*, as it is called, we have the data from which we can calculate both the number of collisions in a second and also the mean path between two successive collisions. The results, as we must expect, are of the same order as the other molecular magnitudes. But inconceivably short as the free[1] path of a molecule certainly is, it is still, in the case of hydrogen gas, 136 times the diameter of the moving body, which would certainly be regarded among men as quite ample elbow-room.

Although, in this lecture, I have as yet had no occasion to mention the radiometer, I have by no means forgotten my main subject, and everything which has been said has had a direct bearing on the theory of this remarkable instrument; and still, before you can understand the great interest with which it is regarded, we must follow out another line of thought, converging on the same point.

One of the most remarkable results of modern science is the discovery that all energy at work on the surface of this planet comes from the sun. Most of you probably saw, at our Centennial Exhibition, that great artificial cascade in Machinery Hall, and were impressed with the power of the steam-pump which could keep flowing such a mass of water. But, also, when you stood before the falls at Niagara, did you realize the fact that the enormous floods of water, which you saw surging over those cliffs, were in like manner supplied by an all-powerful pump, and that pump the sun? And not only is this true, but it is equally true that every drop of water that falls, every wave that beats, every wind that blows, every creature that moves on the surface of the earth, one and all, are animated by that mysterious effluence we call the sunbeam. I say mysterious effluence; for how that power is trans-

[1] There is an obvious distinction between the free and the disturbed path of a molecule, and we cannot overlook in our calculations the perturbations which the collisions necessarily entail. Such considerations greatly complicate the problem, which is far more difficult than would appear from the superficial view of the subject that can alone be given in a popular lecture.

mitted over those 92,000,000 miles between the earth and the sun, is still one of the greatest mysteries of Nature.

In the science of optics, as is well known, the phenomena of light are explained by the assumption that the energy is transmitted in waves through a medium which fills all space, called the luminiferous ether, and there is no question that this theory of Nature, known in science as the Undulatory Theory of Light, is, as a working hypothesis, one of the most comprehensive and searching which the human mind has ever framed. It has both correlated known facts and pointed the way to remarkable discoveries. But, the moment we attempt to apply it to the problem before us, it demands conditions which tax even a philosopher's credulity.

As sad experience on the ocean only too frequently teaches, energy can be transmitted by waves as well as in any other way. But every mechanic will tell you that the transmission of energy, whatever be the means employed, implies certain well-known conditions. Let it be that the energy is to be used to turn the spindles of a cotton-mill. The engineer can tell you just how many horse-power he must supply for every working-day, and it is equally true that a definite amount of energy must come from the sun to do each day's work on the surface of the globe. Further, the engineer will also tell you that, in order to transmit the power from his turbine or his steam-engine, he must have shafts and pulleys and belts of adequate strength, and he knows in every case what is the lowest limit of safety. In like manner, the medium through which the energy which runs the world is transmitted must be strong enough to do the immense work put upon it; and, if the energy is transmitted by waves, this implies that the medium must have an enormously great elasticity, an elasticity vastly greater than that of the best-tempered steel.

But turn now to the astronomers, and learn what they have to tell us in regard to the assumed luminiferous ether through which all this energy is supposed to be transmitted. Our planet is rushing in its orbit around the sun at an average rate of over 1,000 miles a minute, and makes its annual journey of some 550,000,000 miles in 365 days 6 hours 9 seconds and $\frac{8}{10}$ of a second. Mark the tenths; for astronomical observations are so accurate that, if the length of the year varied permanently by the tenth of a second, we should know it; and you can readily understand that, if there were a medium in space which offered as much resistance to the motion of the earth as would gossamer threads to a race-horse, the planet could never come up to time, year after year, to the tenth of a second.

How, then, can we save our theory, by which we set so much, and rightly, because it has helped us so effectively in studying Nature? If we may be allowed such an extravagant solecism, let us suppose that the engineer of our previous illustration was the hero of a fairy-tale. He has built a mill, set a steam-engine in the basement, arranged his

spindles above, and is connecting the pulleys by the usual belts, when some stern necessity requires him to transmit all the energy with cobwebs. Of course, a good fairy comes to his aid, and what does she do? Simply makes the cobwebs indefinitely strong. So the physicists, not to be outdone by any fairies, make their ether indefinitely elastic, and their theory lands them just here, with a medium filling all space, thousands of times more elastic than steel, and thousands on thousands of times less dense than hydrogen gas. There must be a fallacy somewhere, and I strongly suspect it is to be found in our ordinary materialistic notions of causation, which involve the old metaphysical dogma, "*nulla actio in distans*," and which in our day have culminated in the famous apothegm of the German materialist, "Kein Phosphor kein Gedanke."

But it is not my purpose to discuss the doctrines of causation, and I have dwelt on the difficulty, which this subject presents in connection with the undulatory theory, solely because I wished you to appreciate the great interest with which scientific men have looked for some direct manifestation of the mechanical action of light. It is true that the ether-waves must have dimensions similar to those of the molecules discussed above, and we must expect, therefore, that they would act primarily on the molecules and not on masses of matter. But still the well-known principles of wave-motion have led competent physicists to maintain that a more or less considerable pressure ought to be exerted by the ether-waves on the surfaces against which they beat, as a partial resultant of the molecular tremors first imparted. Already, in the last century, attempts were made to discover some evidence of such action, and in various experiments the sun's direct rays were concentrated on films, delicately suspended and carefully protected from all other extraneous influences, but without any apparent effect; and thus the question remained until about three years ago, when the scientific world were startled by the announcement of Mr. Crookes, of London, that, on suspending a small piece of blackened alder-pith in the very perfect vacuum which can now be obtained with the mercury-pump, invented by Sprengel, he had seen this light body actually repelled by the sun's rays; and they were still more startled, when, after a few further experiments, he presented us with the instrument he called a radiometer, in which the sun's rays do the no inconsiderable work of turning a small wheel. Let us examine for a moment the construction of this remarkable instrument.

The moving part of the radiometer is a small horizontal wheel, to the ends of whose arms are fastened vertical vanes, usually of mica, and blackened on one side. A glass cap forms the hub, and by the glass-blower's art the wheel is inclosed in a glass bulb, so that the cap rests on the point of a cambric needle; and the wheel is so delicately balanced on this pivot that it turns with the greatest freedom. From the interior of the bulb the air is now exhausted by means of the Sprengel pump, until less than $\frac{1}{1000}$ of the original quantity is left,

and the only opening is then hermetically sealed. If, now, the sun's light or even the light from a candle shines on the vanes, the blackened surfaces—which are coated with lamp-black—are repelled, and, these being symmetrically placed around the wheel, the several forces conspire to produce the rapid motion which results. The effect has all the appearance of a direct mechanical action exerted by the light, and for some time was so regarded by Mr. Crookes and other eminent physicists, although in his published papers it should be added that Mr. Crookes carefully abstained from speculating on the subject—aiming, as he has since said, to keep himself unbiased by any theory, while he accumulated the facts upon which a satisfactory explanation might be based.

Singularly, however, the first aspect of the new phenomena proved to be wholly deceptive; and the motion, so far from being an effect of the direct mechanical action of the waves of light, is now believed to be a new and very striking manifestation of molecular motion. To this opinion Mr. Crookes himself has come, and in a recent article he writes: "Twelve months' research, however, has thrown much light on these actions; and the explanation afforded by the dynamical theory of gases makes, what was a year ago obscure and contradictory, now reasonable and intelligible."

As is frequently the case in Nature, the chief effect is here obscured by various subordinate phenomena, and it is not surprising that a great difference of opinion should have arisen in regard to the cause of the motion. This would not be an appropriate place to describe the numerous investigations occasioned by the controversy, many of which show in a most striking manner how easily experimental evidence may be honestly misinterpreted in support of a preconceived opinion. I will, however, venture to trespass further on your patience, so far as to describe the few experiments by which very early in the controversy I satisfied my own mind on the subject.

When two years ago I had for the first time an opportunity of experimenting with a radiometer, the opinion was still prevalent that the motion of the wheel was a direct mechanical effect of the waves of light, and therefore that the impulses came from the outside of the instrument, the waves passing freely through the glass envelope. At the outset this opinion did not seem to me to be reasonable, or in harmony with well-known facts; for, knowing how great must be the molecular disturbance caused by the sun's rays as shown by their heating power, I could not believe that a residual action, such as has been referred to, would first appear in these delicate phenomena observed by Mr. Crookes, and should only be manifested in the vacuum of a mercury-pump.

On examining the instrument, my attention was at once arrested by the lampblack coating on the alternate surfaces of the vanes; and from the remarkable power of lampblack to absorb radiant heat it was

evident at once that, whatever other effects the rays from the sun or from a flame might cause, they must necessarily determine a constant difference of temperature between the two surfaces of the vanes; and the thought at once occurred that, after all, the motion might be a direct result of this difference of temperature—in other words, that the radiometer might be a small heat-engine, whose motions, like those of every other heat-engine, depend on the difference of temperature between its parts.

But, if this were true, the effect ought to be proportional solely to the heating power of the rays, and a very easy means of roughly testing this question was at hand. It is well known that an aqueous solution of alum, although transmitting light as freely as the purest water, powerfully absorbs those rays, of any source, which have the chief heating power. Accordingly, I interposed what we call an alum-cell in the path of the rays shining on the radiometer, when, although the light on the vanes was as bright as before, the motion was almost completely arrested.

This experiment, however, was not conclusive, as it might still be said that the *heat*-giving rays acted *mechanically;* and it must be admitted that the chief part of the energy in the rays, even from the most brilliant luminous sources, always takes the form of heat. But, if the action is mechanical, the reaction must be against the medium through which the rays are transmitted, while, if the radiometer is simply a heat-engine, the action and reaction must be, ultimately at least, between the heater and the cooler, which in this case are respectively the blackened surfaces of the vanes and the glass walls of the inclosing bulb; and here, again, a very easy method of testing the actual condition at once suggested itself.

If the motion of the radiometer-wheel is an effect of mechanical impulses transmitted in the direction of the beam of light, it was certainly to be expected that the beam would act on the lustrous as well as on the blackened mica surfaces, however large might be the difference in the resultants producing mechanical motion in consequence of the great absorbing power of the lampblack. Moreover, since the instrument is so constructed that of two vanes, on opposite sides of the wheel, one always presents a blackened and the other a lustrous surface to an incident beam, we should further expect to find in the motion of the wheel a differential phenomenon, due to the unequal action of the light on these surfaces. On the other hand, if the radiometer is a heat-engine, and the reaction takes place between the heated blackened surfaces of the vanes and the colder glass, it is evident that the total effect will be simply the sum of the effects at the several surfaces.

In order to investigate the question thus presented, I placed the radiometer before a common kerosene-lamp, and observed, with a stop-watch, the number of seconds elapsed during ten revolutions of the little wheel. Finding that this number was absolutely constant, I next

screened one-half of the bulb, so that only the blackened faces were exposed to the light as the wheel turned them into the beam. Again, I several times observed the number of seconds during ten turns, which, although equally constant, was greater than before. Lastly, I screened the blackened surfaces so that, as the wheel turned, only the lustrous surfaces of mica were exposed to the light, when, to my surprise, the wheel continued to turn in the same direction as before, although much more slowly. It appeared as if the lustrous surfaces were attracted by the light. Again I observed the time of ten revolutions, and here I have collected my results, reducing them, in the last column, so as to show the corresponding number of revolutions in the same time:

CONDITIONS.	Time of Ten Revolutions.	No. of Revolutions in same Time.
Both faces exposed	8 seconds.	319
Blackened faces only	11 "	232
Mica faces only	29 "	88

It will be noticed that 88 + 232 equals very nearly 319. Evidently the effect, so far from being differential, is concurrent. Hence, the action which causes the motion must take place between the parts of the instrument, and cannot be a direct effect of impulses imparted by ether-waves; or else we are driven to the most improbable alternative, that lampblack and mica should have such a remarkable selective power that the impulses imparted by the light should exert a repulsive force at one surface and an attractive force at the other. Were there, however, such an improbable effect, it must be independent of the thickness of the mica vanes; while on the other hand, if, as seemed to us now most probable, the whole effect depended on the difference of temperature between the lampblack and the mica, and if the light produced an effect on the mica surface only because, the mica plate being diathermous to a very considerable extent, the lampblack became heated through the plate more than the plate itself, then it would follow that, if we used a thicker mica plate, which would absorb more of the heat, we ought to obtain a marked difference of effect. Accordingly, we repeated the experiment with an equally sensitive radiometer, which we made for the purpose, with comparatively thick vanes, and with this the effect of a beam of light on the mica surface was absolutely null, the wheel revolving in the same time, whether these faces were protected or not.

But one thing was now wanting to make the demonstration complete. A heat-engine is reversible, and if the motion of the radiometer depended on the circumstance that the temperature of the blackened faces of the vanes was higher than that of the glass, then by reversing the conditions we ought to reverse the motion. Accordingly, I carefully heated the glass bulb over a lamp, until it was as hot as the hand

would bear, and then placed the instrument in a cold room, trusting to the great radiating power of lampblack to maintain the temperature of the blackened surfaces of the vanes below that of the glass. Immediately the wheel began to turn in the opposite direction, and continued to turn until the temperature of the glass came into equilibrium with the surrounding objects.

These early experiments have since been confirmed to the fullest extent, and no physicist at the present day can reasonably doubt that the radiometer is a very beautiful example of a heat-engine, and it is the first that has been made to work continuously by the heat of the sunbeam. But it is one thing to show that the instrument is a heat-engine, and quite another thing to explain in detail the manner in which it acts. In regard to the last point, there is still room for much difference of opinion, although physicists are generally agreed in referring the action to the residual gas that is left in the bulb. As for myself, I became strongly persuaded—after experimenting with more than one hundred of these instruments, made under my own eye, with every variation of conditions I could suggest—*that the effect was due to the same cause which determines gas-pressure*, and, according to the dynamical theory of gases, this amounts to saying that the effect is due to molecular motion. I have not time, however, to describe either my own experiments on which this opinion was first based, or the far more thorough investigations since made by others, which have served to strengthen the first impression.[1] But, after our previous discussions, a few words will suffice to show how the molecular theory explains the new phenomena.

Although the air in the bulb has been so nearly exhausted that less than the one-thousandth part remains, yet it must be borne in mind that the number of molecules left behind is by no means inconsiderable. As will be seen by referring to our table, there must still be no less than 311,000 million million in every cubic inch. Moreover, the absolute pressure which this residual gas exerts is a very appreciable quantity. It is simply the one-thousandth of the normal pressure of the atmosphere, that is, of $14\frac{7}{10}$ pounds on a square inch; which is equivalent to a little over 100 grains on the same area. Now, the area of the blackened surfaces of the vanes of an ordinary radiometer measures just about a square inch, and the wheel is mounted so delicately that a constant pressure of one-tenth of a grain would be sufficient to produce rapid motion. So that a difference of pressure on the opposite faces of the vanes, equal to one one-thousandth of the whole amount, is all that we need account for; and, as can easily be calculated, a difference of temperature of less than half a degree Fahrenheit would cause all this difference in the pressure of the rarefied air.

But you may ask, How can such a difference of pressure exist on

[1] *See* notice of these investigations by the author of this article, in *American Journal of Science and Arts*, September, 1877 (3), xiv., 231.

different surfaces exposed to one and the same medium? and your question is a perfectly legitimate one; for it is just here that the new phenomena seem to belie all our previous experience. If, however, you followed me in my very partial exposition of the mechanical theory of gases, you will easily see that on this theory it is a more difficult question to explain why such a difference of pressure does not manifest itself in every gas medium and under all conditions between any two surfaces having different temperatures.

We saw that gas-pressure is a double effect, caused both by the impact of molecules and by the recoil of the surface attending their rebound. We also saw that when molecules strike a heated surface they rebound with increased velocity, and hence produce an increased pressure against the surface, the greater the higher the temperature. According to this theory, then, we should expect to find the same atmosphere pressing unequally on equal surfaces if at different temperatures; and the difference in the pressure on the lampblack and mica surfaces of the vanes, which the motion of the radiometer-wheel necessarily implies, is therefore simply the normal effect of the mechanical condition of every gas medium. The real difficulty is, to explain why we must exhaust the air so perfectly before the effect manifests itself.

The new theory is equal to the emergency. As has been already pointed out, in the ordinary state of the air the amplitude of the molecular motion is exceedingly small, not over a few ten-millionths of an inch—a very small fraction, therefore, of the height of the inequalities on the lampblack surfaces of the vanes of a radiometer. Under such circumstances, evidently the molecules would not leave the heated surface, but simply bound back and forth between the vanes and the surrounding mass of dense air, which, being almost absolutely a non-conductor of heat, must act essentially like an elastic solid wall confining the vanes on either side. For the time being, and until replaced by convection-currents, the oscillating molecules are as much a part of the vanes as our atmosphere is a part of the earth; and on this system, as a whole, the homogeneous dense air which surrounds it must press equally from all directions. In proportion, however, as the air is exhausted, the molecules find more room and the amplitude of the molecular motion is increased, and when a very high degree of exhaustion is reached the air-particles no longer bound back and forth on the vanes without change of condition, but they either bound off entirely like a ball from a cannon, or else, having transferred a portion of their momentum, return with diminished velocity, and in either case the force of the reaction is felt.[1]

[1] The reader will, of course, distinguish between the differential action on the opposite faces of the vanes of the radiometer and the reaction between the vanes and the glass which are the heater and the cooler of the little engine. Nor will it be necessary to remind any student that a popular view of such a complex subject must be necessarily partial. In the present case we not only meet with the usual difficulties in this respect, but,

Thus it appears that we have been able to show by very definite experimental evidence that the radiometer is a heat-engine. We have also been able to show that such a difference of temperature as the radiation must produce in the air in *direct* contact with the opposite faces of the vanes of the radiometer would determine a difference of tension, which is sufficient to account for the motion of the wheel. Finally, we have shown, as fully as is possible in a popular lecture, that, according to the mechanical theory of gases, such a difference of tension would have its normal effect only in a highly-rarefied atmosphere, and thus we have brought the new phenomena into harmony with the general principles of molecular mechanics previously established.

More than this cannot be said of the steam-engine, although, of course, in the older engine the measurements on which the theory is based are vastly more accurate and complete. But the moment we attempt to go beyond the general principles of heat-engines, of which the steam-engine is such a conspicuous illustration, and explain how the heat is transformed into motion, we have to resort to the molecular theory just as in the case of the radiometer; and the motion of the steam-engine seems to us less wonderful than that of the radiometer, only because it is more familiar and more completely harmonized with the rest of our knowledge. Moreover, the very molecular theory which we call upon to explain the steam-engine involves consequences which, as we have seen, have been first realized in the radiometer; and thus it

moreover, the principles of molecular mechanics have not been so fully developed as to preclude important differences of opinion between equally competent authorities in regard to the details of the theory. To avoid misapprehension, we may here add that, in order to obtain in the radiometer a reaction between the heater and the cooler, it is not necessary that the space between them should actually be crossed by the moving molecules. It is only necessary that the momentum should be transferred across the space, and this may take place along lines consisting of many molecules each. The theory, however, shows that such a transfer can only take place in a highly-rarefied medium. In an atmosphere of ordinary density, the accession of heat which the vanes of a radiometer might receive from a radiant source would be diffused through the mass of the inclosed air. This amounts to saying that the momentum would be so diffused, and hence, under such circumstances, the molecular motion would not determine any reaction between the vanes and the glass envelope. Indeed, a dense mass of gas presents to the conduction of heat, which represents momentum, a wall far more impenetrable than the surrounding glass, and the diffusion of heat is almost wholly brought about by convection-currents which rise from the heated surfaces. It will thus be seen that the great non-conducting power of air comes into play to prevent not only the transfer of momentum from the vanes to the glass, but also, almost entirely, any direct transfer to the surrounding mass of gas. Hence, as stated above, the heated molecules bound back and forth on the vanes without change of condition, and the mass of the air retains its uniform tension in all parts of the bulb, except in so far as this is slowly altered by the convection-currents just referred to. As the atmosphere, however, becomes less dense, the diffusion of heat by convection diminishes, and that by molecular motion (conduction) increases until the last greatly predominates. When, now, the exhaustion reaches so great a degree that the heat, or momentum, is rapidly transferred from the heater to the cooler by an exaggeration, or, possibly, a modification of the mode of action we call conduction, then we have the reaction on which the motion of the radiometer-wheel depends.

is that this new instrument, although disappointing the first expectations of its discoverer, has furnished a very striking confirmation of this wonderful theory. Indeed, the confirmation is so remote and yet so close, so unexpected and yet so strong, that the new phenomena almost seem to be a direct manifestation of the molecular motion which our theory assumes; and when a new discovery thus confirms the accuracy of a previous generalization, and gives us additional reason to believe that the glimpses we have gained into the order of Nature are trustworthy, it excites, with reason, among scientific scholars the warmest interest.

And when we consider the vast scope of the molecular theory, the order on order of existences which it opens to the imagination, how can we fail to be impressed with the position in which it places man midway between the molecular cosmos on the one side and the stellar cosmos on the other—a position in which he is able in some measure, at least, to study and interpret both?

Since the time to which we referred at the beginning of this lecture, when man's dwelling-place was looked at as the centre of a creation which was solely subservient to *his* wants, there has been a reaction to the opposite extreme, and we have heard much of the utter insignificance of the earth in a universe among whose immensities all human belongings are but as a drop in the ocean. When now, however, we learn from Sir William Thomson that the drop of water in our comparison is itself a universe, consisting of units so small that, were the drop magnified to the size of the earth, these units would not exceed in magnitude a cricket-ball,[1] and when, on studying chemistry, we still further learn that these units are not single masses but systems of atoms, we may leave the illusions of the imagination from the one side to correct those from the other, and all will teach us the great lesson that man's place in Nature is not to be estimated by relations of magnitude, but by the intelligence which makes the whole creation his own.

But, if it is man's privilege to follow both the atoms and the stars in their courses, he finds that while thus exercising the highest attributes of his nature he is ever in the presence of an immeasurably superior intelligence, before which he must bow and adore, and thus come to him both the assurance and the pledge of a kinship in which his only real glory can be found.

[1] *Nature*, No. 22, March 31, 1870.

PERSONAL REMINISCENCES OF SOME DECEASED SAVANTS.

By CARL VOGT.

THEY die in such rapid succession! You hardly have time, after returning from a funeral, to think about who is to be the successor of the lamented dead, when you hear of the demise of another illustrious colleague. The members of the Paris Academy of Sciences can scarcely find competent successors for the dead celebrities among the few representatives of the new generation; yet the places of those celebrities must be filled, although everybody knows that the new men will but poorly fill those places. Leverrier, Becquerel, Regnault, Claude Bernard—where are the names among the younger *savants* that equal them, or that might be hoped one day to eclipse their predecessors?

I was fortunate enough to be personally acquainted with these four men, and hence I may be permitted to add to the numerous notices that have been written of their signal scientific achievements some impressions which I have retained from my personal intercourse with them.

In the years 1834 and 1835 I worked as a very young student of medicine in Liebig's laboratory at Giessen—in the summer of 1834 only now and then, but later continually—with the firm determination of turning my back upon medicine as soon as possible, and of becoming a professional chemist. The former resolution I succeeded in carrying out, but I had to leave the chemical career, originally from want of means. At that time only a few young men worked in the laboratory—among them a mercurial, gay Frenchman, who was known all over Giessen on account of a large yellow spot upon his elegantly-made blue coat. Demarçay—that was the name of our Parisian—refused to remove the spot, which had been caused by some sort of acid, nor would he cast the coat aside. In Giessen, he said, there was no tailor competent to mend or only to imitate a Paris-made garment. One day Liebig entered the laboratory with a slender little Frenchman, who wore the same kind of blue coat, but without a spot, and introduced him to us as M. Regnault, a student of the Paris School of Mines, who was to familiarize himself here with organic analysis, then the hobby of *savants*. Demarçay was of dark complexion, with raven-black hair, witty, and fond of practical jokes; Regnault was ruddy and fair, with long, light-colored hair, grave, but confiding. He spoke German very well, and, as he had a seat by my side, we were not long in becoming good friends. He was the perfect type of a rather delicate North-German or Scandinavian youth whom you might have almost taken for a boy of fifteen, so slight and fragile was his form, so amiable and pleas-

ing his whole bearing. After a few weeks he disappeared as he had come. "I must go," he said, "but I hope to be back soon." We were surprised to discover now that Demarçay had had his yellow spot removed—it was owing to Regnault's urgent representations—and, at the same time, we learned that the time granted for scientific journeys to every engineer of the School of Mines had expired in Regnault's case, but that Liebig, who had immediately discerned the eminent talents of the young man, had interceded in Regnault's behalf in Paris, in order that another sojourn at Giessen might be allowed to him. The request was granted, and Regnault came back.

Ten years later my destiny brought me to Paris. Agassiz, with whom I had worked five years at Neufchâtel, had emigrated to America, whither I did not want to accompany him. I was indebted to him for letters of introduction to some of the prominent members of the Academy of Sciences, which was then split into two great parties: one, headed by Arago, embraced the few republicans, the mathematicians and physicists; the other, led by the elder Brongniart, embraced most of the naturalists, the chemists, and the Orleanists. I had been recommended to the latter group; with Arago I was brought into closer contact by several radical Alsacians, whose acquaintance I had made partly during my flight from the gendarmes of his royal highness the Grand-duke of Hesse, and partly afterward in Switzerland. I was to make my living in Paris by reporting the proceedings of the Academy of Sciences for the Augsburg *Universal Gazette.* Upon entering the gloomy hall for the first time, I immediately noticed Regnault; he sat with his dreamy gaze before a few papers, as before the retorts in the laboratory; and, after the lapse of ten years, looked as young and fresh as at Giessen. Thus I saw him for three years in Paris, and again after long intervals; and when, during the Franco-German War, he came to Geneva, broken-hearted because of the death of his excellent son, who, in his youth, had caused him many a pang by his mad freaks, but had afterward filled his heart with just pride and joy, the deep furrows of suffering, and the consequences of a dangerous fall several years before at the porcelain-factory of Sèvres, had been unable to obliterate his youthful appearance completely. But his last years were a long, slow agony; death had made the most cruel gaps in his family already, prior to the death of his son; the war had rudely destroyed the instruments which he had patiently collected for many years at Sèvres, and this destruction had affected him the more painfully, as the utmost precision and the most conscientious calculation formed the most essential peculiarity of his labors. Ever studious to detect the most insignificant sources of errors, to reduce miscalculations to their very minimum, to bring his apparatus and instruments to the highest degree of efficiency and technical perfection, Regnault will always be a shining model for those moving in similar paths of experimental physics.

The elder Becquerel, who died about the same time, at an advanced age, after life-long toils, was already a gray-haired man when I became acquainted with him in the Société Philomatique at Paris. His son, who had a seat beside him in the Academy, was then a zealous member of that society, whose meetings I attended regularly, because it was the favorite debating-ground of the younger *savants*, who displayed more zeal in their discussions than was witnessed in the Academy. The old gentleman frequently accompanied his son, but I never became intimate with him.

Before Haussmann had revolutionized the appearance of Paris, and prior to the Revolution of 1848, there existed a Rue Copeau, leading from the Rue Mouffetard, the headquarters of the rag-pickers, to the small entrance-gate of the Jardin des Plantes, and upon which the grand portal of the Pitié Hospital abutted. Diagonally across the street from this portal there was a house bearing the number 4, where most of the foreign naturalists, who worked for some time at the Jardin des Plantes, had rooms. A well-known anatomist, Strauss-Durkheim, author of an excellent anatomy of the cockchafer, upon which he had toiled for twenty years, presided at the table of the house, and knew how to ingratiate himself with the proprietresses, two spinster ladies, who were as gaunt and slender as Papa Strauss was broad and fat. The rooms had special names, derived from the illustrious zoölogists, anatomists, and botanists, who had inhabited them. For one hundred francs a month I had the two rooms of Johannes Müller on the first floor, overlooking the gardens, together with board. Besides the naturalist boarders, many old friends from the neighboring streets took their breakfast and dinner there. They were mostly quiet people, living on the interest of a small capital, and who attended all lectures at the Jardin des Plantes, at the Collége de France, and even at the more distant Sorbonne, solely because they there found warm rooms in the winter-time. The conversation at the dinner-table was rarely very animated. Papa Strauss, whose bald head emerged from behind a very large green lamp-shade, like the full moon from behind a dark wreath of clouds, grunted discontentedly whenever louder tones fell upon his ears.

But, at times, all Papa Strauss's grunts were fruitless, and such was especially the case when the young medical students of the Pitié Hospital came to visit us, and conversed with the naturalists of the house about the scientific questions of the day. Two of them were remarkably tall. One, a very long, slender, lively, witty, and sarcastic young man, was a nephew of Cloquet, the celebrated surgeon, and, to distinguish him from his uncle, the students called him only "Le Grand Serpent." He went afterward, as physician of the shah, to Persia, and was, during a chase, assassinated by unknown murderers, whom the shah himself had probably hired. The other, by far graver, with a melancholy expression of countenance, was Claude Bernard. Magendie's experiments, Longet's investigations of the physiology of the ner-

vous system, were at that time most eagerly discussed. Claude Bernard said very little, but what he did say was terse and to the point. He only became excited when anybody undertook to question the experiments and achievements of his teacher Magendie, whose assistant he afterward became at the Collége de France.

While he afterward rose step by step from one dignity and distinction to another, ever steadily pursuing those memorable researches which made him the foremost physiologist of our times, I lost sight of him as a personal acquaintance. I came to Paris only in vacation-time, and then Claude Bernard was at his country-seat in the environs of his birthplace, Lyons. If after a youth of terrible privations—very often he did not know in the morning how to get his dinner—he could now feel happy, seeing that everything which the ambition of the *savant* could wish for was offered to him, the highest positions at the universities and in the learned societies, a seat in the Senate, for which he was indebted to his scientific eminence, and not to any political services, he was weighed down, on the other hand, by serious bodily ailments and by the saddest of domestic misfortunes. At first I did not recognize him when, pleasantly and kindly, as of old, but gray-haired, and with his head inclined on one side, he stepped up to me at a provincial meeting, and reminded me of the old times in the Rue Copeau and the Pitié Hospital. "I have passed through a great deal since that time," he said to me, "which may have left some traces in my appearance—for I notice that you look at me in surprise—but let us chat a little about those times and about our old friends; it does me good!"

At the same time I became acquainted with Leverrier. As I have said already in this article, I had been brought into contact with the leaders of the two great parties in the Academy of Sciences, and had been kindly received by both. In the *salons* of Brongniart and Milne-Edwards I saw most of the naturalists; at the house of Martin de Strasbourg, as the well-known deputy was called, I frequently met François Arago, who was then intent upon learning German in order to be able to distinguish the pronunciations of Encke and Henoke, whom, as official reporter of the Academy, he had often occasion to mention. But that genuine son of La Provence was eminently unsuccessful in that respect, nor did he ever learn to pronounce my own name correctly; but, as his German teacher had him to read Schiller's "William Tell," the *vogt*[1] of the tragedy became confounded in his head with the living Vogt, and to the great merriment of everybody he called me "Gessler," to which name he obstinately clung.

One day a young man entered my room. From his appearance I should have unhesitatingly taken him for the son of a Westphalian peasant; for he was fair-haired, rosy-cheeked, and solidly built. It was Leverrier, who delivered a sort of address to me, confounding Vogt

[1] Governor.

and Gessler all the time, and finally held out to me a quarto volume filled with figures, with the request to promote his election to the Academy. I stared at him as a cow will stare at a new stable-door, and then burst into loud laughter, which almost dumfounded the young candidate. The idea that I should be able to do anything for the promotion of his candidature seemed as ridiculous as he looked upon it as a matter of course. But, when I told him that I deemed my assistance utterly superfluous, and that I had heard all my friends of the Brongniart party talk about his election as a foregone conclusion, he almost embraced me for joy, and said that his visit to me was the most agreeable he had paid for a long time. He urged me to visit him, to see his wife and his little son, and so on. Thus he left me, flushed with excitement, and, when I told a friend at the Jardin des Plantes that the whole affair seemed utterly incomprehensible to me, he said: "You are a novice in such things. Do you know what a candidate for the Academy is? The unhappiest man in the world. He has to hire a carriage for a month; he rides out early in the morning to pay visits, and comes home late in the evening, fearfully tired. He has no time for eating and sleeping; for of nights he dreams of fresh essays, and finally sinks half dead into his easy-chair. He visits everybody, even the cousin of the dress-maker who sews for the aunt of the wife of an academician; and you are surprised that Leverrier should come to see you? After a while, when I am a candidate, I shall also pay you a visit, although I see you every day at the Jardin des Plantes. Otherwise you might take offense."

Leverrier had, at that time, a very pleasant home. His wife was a handsome, amiable woman, his son was a fat, rosy-cheeked boy, and his daily visitor was Arago, who knew how to interest the smallest as well as the largest circles by his lively and witty conversation. He was a republican, like Arago, to whom he was indebted for everything, and whom he afterward treated in a manner which was justly and harshly criticised. For he became a rabid reactionist, and he whom everybody had taken for a frank, noble character was soon looked upon as the most rancorous man in Paris. People admired the astronomical calculator and the indefatigable student; but they hated and even despised the colleague and the superior. I am inclined to think that all the members of the Academy together were not so cordially execrated during their lifetime as Leverrier alone. I was averse to renew my intimacy with the man who had become repugnant to me.

I do not propose to analyze here the scientific merits of the men whom France has recently lost. If Becquerel and Regnault were known only in professional circles, the name of Leverrier is familiar to all who have heard of the planet Neptune, which he so ingeniously discovered; and Claude Bernard is not unknown to cultivated people, as his fertile pen has popularized physiological knowledge and investigations. Only one of the four, Becquerel, was popular as a lecturer; Claude Bernard

was the only one among them whose views reached far beyond his special field of knowledge, and, for this reason, he knew how to adapt the style of his writings to the requirements of cultivated society.

In conclusion, I should like to draw attention to one thing. None of these four men, who achieved lasting fame in so many different branches of science, had been originally destined for scientific pursuit. What they were and what they achieved were due to themselves and to their iron will. Becquerel had left the Polytechnic School in 1808, in his twentieth year, had become a lieutenant of engineers, had been promoted to the command of a battalion in the Spanish campaigns, and left the service after the battle of Waterloo in order to devote himself to the study of physics; Leverrier and Regnault had originally been clerks in stores, and had studied in their leisure hours until they were able to gain admittance to the Polytechnic School; Claude Bernard had come to Paris with hardly anything in his pocket but a tragedy, and he had first dabbled in literature. Hard, indescribably hard work, untold privations, and struggles of all kinds, enabled these men to attain the high position which they will always hold in the history of science. To them may be applied what one of my friends once said in regard to an eminent *savant:* "Dans sa jeunesse il a tiré le diable par la queue et mangé de la vache enragée; mais il a réussi, parce qu'il avait le feu sacré!"

EVOLUTION OF CEREMONIAL GOVERNMENT.

By HERBERT SPENCER.

IV. PRESENTS.

WHEN we read that Cook "presented the king [of Otaheite] with two large hatchets, some showy beads, a looking-glass, a knife, and some nails;" or when Speke, describing his reception by the King of Uganda, narrates—"I then said I had brought the best shooting-gun in the world—Whitworth's rifle—which I begged he would accept, with a few other trifles"—we are reminded how travelers in general, coming in contact with strange peoples, propitiate them by gifts. Two concomitant results are achieved. There is the immediate gratification caused by the worth of the thing given, which tends to beget a friendly mood in those approached; and there is the tacit expression of a desire to please, which has a like effect. It is from the last of these that the development of gift-making as a ceremony proceeds.

The alliance between mutilations and presents—between offering a part of the body and offering something else—is well shown by a statement of Garcilasso, respecting the ancient Peruvians; which, at the same time, shows how present-making becomes a propitiatory act apart

from the value of the thing presented. Describing people who carry burdens over the high passes, he speaks of them as unloading themselves on the top, and then severally saying to the god Pachacamac:

"'I give thanks that this has been carried,' and in making an offering they pulled a hair out of their eyebrows, or took the herb called *cuca* from their mouths, as a gift of the most precious things they had. Or, if there was nothing better, they offered a small stick or piece of straw, or even a piece of stone or earth. There were great heaps of these offerings at the summits of passes over the mountains."

Though, coming to us in this unfamiliar form, these offerings of parts of themselves, or of things they prized, or else of worthless things, seem strange, they will seem less strange on remembering that at the foot of a way-side crucifix in France may any day be seen a heap of small crosses severally made of two bits of lath nailed together. Intrinsically of no more value than these straws, sticks, and stones, the Peruvians offered, they similarly force on our attention the truth that the act of presentation passes into a ceremony expressing the wish to conciliate. How natural is this substitution of a nominal giving for a real giving, where real giving is impracticable, we are shown even by intelligent animals. A retriever, accustomed to please his master by fetching killed birds, etc., will fall into the habit at other times of fetching something to show his desire to please. On first seeing in the morning, or after an absence, one he is friendly with, he will join, with the usual demonstrations of joy, the seeking and bringing in his mouth a dead leaf, a twig, or any small available object lying near. And this example, while serving to show the natural genesis of this propitiatory ceremony, serves also to show how deep down there begins the process of symbolization; and how, at the outset, the symbolic act is as near a repetition of the act symbolized as the circumstances allow.

Prepared, as we thus are, to trace the development of gift-making into a ceremony, let us now observe its several varieties, and the social arrangements eventually derived from them.

In headless tribes, and in tribes of which the headship is unsettled, and in tribes of which the headship though settled is feeble, the making of presents does not become an established usage. Australians, Tasmanians, Fuegians, are instances; and on reading through accounts of wild American races that are little organized, like the Esquimaux, Chinooks, Snakes, Comanches, Chippewas, etc., or organized in a democratic manner, like the Iroquois and the Creeks, we find, along with absence of strong personal rule, scarcely any mention of gift-making as a political observance.

In apt contrast come the descriptions of usages among those American races which in past times reached, under despotic governments, considerable degrees of civilization. Torquemada tells us that in Mex-

ico, "when any one goes to salute the lord or king, he takes with him flowers and gifts." So too of the Chibchas we read that, "when they brought a present in order to negotiate or speak with the cazique (for no one went to visit him without bringing a gift), they entered with the head and body bent downward;" and among the ancient Yucatanese, "when there was hunting or fishing or salt-carrying, they always gave a part to the lord." People of other types, as the Malayo-Polynesians, living in kindred stages of social progress under the undisputed sway of chiefs, exemplify this same custom. Speaking of the things they bartered to the Tahitian populace for food, native cloth, etc., Forster says: "However, we found that after some time all this acquired wealth flowed as presents, or voluntary acknowledgments, into the treasure of the various chiefs; who, it seems, were the only possessors of all the hatchets and broad-axes." In Feejee, again, "whoever asks a favor of a chief, or seeks civil intercourse with him, is expected to bring a present."

In these last cases we may see how this making of presents to the chief passes from a voluntary propitiation into a compulsory propitiation; for, on reading that "the Tahitian chiefs plundered the plantations of their subjects at will," and that in Feejee "chiefs take the property and persons of others by force," it becomes manifest that present-making has come to be the giving of a part to prevent loss of the whole. It is the policy at once to satisfy cupidity and to express submission. "The Malagasy, slaves as well as others, occasionally make presents of provisions to their chiefs, as an acknowledgment of homage." And it is inferable that, in proportion to the power of chiefs, will be the anxiety to please them, both by forestalling their greedy desires and by displaying loyalty.

In few if any cases, however, does the carrying of gifts to a chief become so developed a usage in a simple tribe. At first, the head-man, not much differentiated from the rest, and not surrounded by men ready to enforce his will, fails to impress other members of the tribe with a fear great enough to make present-giving an habitual ceremony. It is only in compound societies, formed by the overrunning of many tribes by a conquering tribe, of the same race or another race, that there comes a governing class, formed of head-chiefs and sub-chiefs, sufficiently distinguished from the rest, and sufficiently powerful to inspire the required awe. The above examples are all taken from societies in which kingship has been reached.

A more extended form is, of course, simultaneously assumed by this ceremony. For, where along with subordinate rulers there exists a chief ruler, he has to be propitiated both by the people at large and by the subordinate rulers. Hence two kinds of gift-making.

A case in which the usage has retained its primitive character is furnished by Timbuctoo. Here "the king does not levy any tribute

on his subjects or on foreign merchants, but he receives presents." But Caillié adds: "There is no regular government. The king is like a father ruling his children." When disputes arise, he "assembles a council of the elders." That is to say, present-giving remains voluntary where the kingly power is not great. Among another African people, the Caffres, we see gifts losing their voluntary character. "The revenue of the king consists of an annual contribution of cattle, first-fruits, etc.;" and "when a Koossa [Caffre] opens his granary he must send a little of the grain to his neighbors, and a larger portion to the king." In Abyssinia, too, there is a like mixture of exactions and voluntary gifts: besides settled contributions taking the form of pieces of cloth and corn, the prince of Tigré receives annual presents. And a kindred system of partially-settled and partially-unsettled donations from people to kings is general throughout East Africa. How, in addition to presents which, having become customary, cease in so far to be propitiatory, there is a tendency to make presents that are propitiatory because unexpected, will be understood on remembering that, where the kingly power has become great, subjects hold their property only on sufferance. When Burton tell us that, in Dahomey, "there is scant inducement to amass riches, of which the owner would assuredly be 'squeezed' as often as he could support the operation;" and when we read of the ancient kings of Bogotá that, "besides the ordinary tributes paid several times a year and other numberless donations, they were absolute . . . lords of the property and life of their subjects"—we may see why, beyond donations which at first voluntary and irregular have become compulsory and regular, there tend ever to grow up new voluntary donations.

If, when a private person brings an offering to his chief or king, the act implies submission, still more does the bringing of an offering by a subordinate ruler to a supreme ruler; here, where disloyalty is more to be feared, the significance of the ceremony as proving loyalty becomes greater. Hence the making of presents grows into a formal recognition of supremacy. In ancient Vera Paz, "as soon as some one was elected king . . . all the lords of the tribes appeared or sent relations of theirs . . . with presents. . . . They declared [at the proclamation] that they agreed to his election and accepted him as king." Among the Chibchas, when a new king came to the throne, "the chief men then took an oath that they would be obedient and loyal vassals, and as a proof of their loyalty each one gave him a jewel and a number of rabbits, etc." Of the Mexicans, Toribio says: "Each year, at certain festivals, those Indians who did not pay taxes, even the chiefs . . . made gifts to the sovereigns . . . in token of their submission." And so in Peru. "No one approached Atahuallpa without bringing a present in token of submission; and, though those who came were great nobles, they entered with the presents on their own backs, and without shoes." The significance of gift-making as implying allegiance is well shown

by two contrasted statements in the records of the Hebrews. Of Solomon it is said that "he reigned over all the kings from the river even unto the land of the Philistines and to the border of Egypt;" and also that "all the kings of the earth sought the presence of Solomon . . . and they brought every man his present . . . a rate year by year." Conversely, it is written that, when Saul was chosen king, "the children of Belial said, How shall this man save us? And they despised him, and brought him no presents." Throughout the remote East, the bringing of presents to the chief ruler has still the same meaning. In Japan it was "a duty of each lord to visit and pay his respects at the imperial court once a year, when they offered presents;" and, further, "the secular monarch pays his respect and duty once a year to the mikado . . . by a solemn embassy and rich presents." In China the meaning of the act as expressing subordination is extremely marked. Along with the statement that "at the installation of the great khan four thousand messengers and embassadors who came loaded with presents assisted at the ceremony," we read that the Mongol officers asked the Franciscan friars dispatched by Innocent IV. "whether the pope knew that the grand-khan was Heaven's son, and that the dominion of the earth belonged of right to him . . . what present they had brought from the pope to the great khan." And equally pronounced is the interpretation put upon gift-making to the monarch in Burmah, where, according to Yule, strenuous efforts were made "on former occasions to introduce foreign envoys as suppliants on 'beg-pardon days' among the vassals and dependents of the empire: their presents being represented as deprecatory offerings to avert deserved punishment for offenses against their liege lord."

Nor does early European history fail to exemplify the meanings of present-giving, alike for general propitiation, for special propitiation, and as signifying loyalty. We learn that during the Merovingian period "on a fixed day, once a year, in the field of March, according to ancient custom, gifts were offered to the kings by the people;" and that this custom continued into the Carolingian period: the presents being of all kinds—food and liquor, horses, gold, silver, jewels, garments. We have the fact that they were made alike by individuals and communities: towns thus expressing their loyalty. And we have the fact that from the time of Gontram, who was overwhelmed with gifts by the inhabitants of Orleans on entering it, onward, it long continued the habit with towns thus to seek the good-will of monarchs who visited them, until eventually such presents became imperative. In ancient England too, when the monarch visited a town, present-making, at first by free-will but at length of necessity, entailed so heavy a loss that in some cases "the passing of the royal family and court was viewed as a great misfortune."

Grouped as above, the evidence will suggest to every reader the in-

ference that from propitiatory presents, voluntary and exceptional to begin with, but becoming as political power strengthens less voluntary and more general, there eventually grow up universal and involuntary contributions—established tribute; and that with the rise of a currency this passes into taxation. How this transformation tends ever to take place, and what are the motives which continually press it on, and change extra voluntary gifts into extra involuntary ones, is well shown by Malcolm's account of the usages in Persia. Speaking of the "irregular and oppressive taxes to which they [the Persians] are continually exposed," he says: "The first of these extra taxes may be termed usual and extraordinary presents. The usual presents to the king are those made annually by all governors of provinces and districts, chiefs of tribes, ministers, and all other officers in high charge, at the feast of Nourouze, or vernal equinox. . . . The amount presented on this occasion is generally regulated by usage; to fall short is loss of office, and to exceed is increase of favor."

That under such kind of pressure regular tribute originated from irregular presents, is in various cases implied both by the nature of the things given and by the growing periodicity of the giving. Supposing them to be acceptable, gifts will naturally be made from among those things which people have that are at once the best and the most abundant. Hence it will happen that when they become regular in an extensive kingdom, they will represent the products of the respective districts; as in ancient Peru, where from one province the people sent fragrant woods, from another cotton, from another emeralds and gold, from another parrots, honey, and wax; or as in ancient Mexico, where the towns paid "what the country afforded, as fish, flesh, corn, cotton, gold, etc.; for they had no money." In other cases where the arrangements are less settled, the gifts from the same place are miscellaneous; as, for instance, those made by towns to early French kings—"oxen, sheep, wine, oats, game, wax-torches, confections, horses, arms, vessels of gold and silver, etc." Clearly, if the making of presents passes into tribute in kind, there will result these varieties of articles; determined sometimes by the character of the locality and sometimes by the abilities of individuals.

The passing of present-making into payment of tribute as it becomes periodic, is well exemplified in some comparatively small societies where governmental power is well established. In Tonga "the higher class of chiefs generally make a present to the king, of hogs or yams, about once a fortnight: these chiefs at the same time receive presents from those below them, and these last from others, and so on, down to the common people." Ancient Mexico, formed of provinces subjugated at various times and dependent in various degrees, exhibited several stages of the transition from presents to tribute. Speaking of the time of Montezuma I., Duran says: "The list of tributes included everything. . . . The provinces . . . made these contributions . . . since they were con-

quered, that the gallant Mexicans might . . . cease to destroy them:" clearly showing that they were at first propitiatory presents. Further we read that "in Meztitlan the tribute was not paid at fixed times . . . but when the lord wanted it. . . . They did not think of heaping up the tribute, but they asked what was wanted at the moment for the temples, the festivals, or the lords." Of the tributes throughout the country of Montezuma, consisting of "provisions, clothing, and a great variety of miscellaneous articles," we are told that "some of these were paid annually, others every six months, and others every eighty days." And then of the gifts made at festivals by some "in tokens of their submission," Toribio says: "In this way it seems manifest that the chiefs, the merchants, and the landed proprietors, were not obliged to pay taxes, but did so voluntarily."

The transition from voluntary gifts to compulsory tribute is traceable in early European history. Among the sources of revenue of the Merovingian kings, Waitz enumerates the free-will gifts of the people on various occasions (especially marriage), besides the yearly presents made originally at the March gatherings, but afterward at other periods about the beginning of the year—voluntary when they began, but increasingly becoming a fixed tax. And then, speaking of these same yearly presents of the people in the Carolingian period, the same writer says they had long lost their voluntary character, and are even described as a tax by Hinckmar. They included horses, gold, silver, and jewels, and (from nunneries) garments, and requisitions for the royal palaces; and he adds that these dues, or *tributa*, were all of a more or less private character; though compulsory, they had not yet become taxes in the literal sense. There is evidence that the voluntary presents, made by towns to potentates on their entry, similarly passed from the voluntary to the compulsory. According to Leber, the express orders of the king were needed to make Paris give presents to the Duke of Anjou in 1584, as also on other occasions to embassadors and foreign monarchs.

In proportion as money-values became more definite, and payments in money became easier, commutation resulted: instance in the Carolingian period, "the so-called *inferenda*—a due originally paid in cattle, now in money;" instance in our own history, the giving of money instead of goods by towns to a king and his suite making a progress through them. The evidence may fitly be closed with the following passage from Stubbs:

> "The ordinary revenue of the English king had been derived solely from the royal estates and the produce of what had been the Folkland, with such commuted payments of feormfultum, or provision in kind, as represented either the reserved rents fron ancient possessions of the crown, or the quasi-voluntary tribute paid by the nation to its chosen head."

In which passage are simultaneously implied the passage from voluntary gifts to involuntary tribute and the commutation of tribute into taxes.

If voluntary gifts, made to propitiate the man who is supreme, by-and-by become tribute and eventually form a settled revenue, may we not expect that gifts made to subordinate men in power, when their aid is wished, will similarly become customary, and at length yield them maintenance? Will not the process above indicated in relation to the major state-functionary repeat itself with the minor state-functionaries? We find that it does so.

First, it is to be noted that, besides the periodic and ordinary presents made in propitiation and acknowledgment of his supremacy, the ruling man in early stages commonly has special presents made to him when called on to use his power in defense or aid of an aggrieved subject. Among the Chibchas, "no one could appear in the presence of a king, cazique, or superior, without bringing a gift, which was to be delivered before the petition was made." In Sumatra, a chief "levies no taxes, nor has any revenue, . . . or other emolument from his subjects, than what accrues to him from the determination of causes." There is a kindred usage in Northwestern India. Of Gulab Singh, a late ruler of Jummoo, Mr. Drew says: "With the customary offering of a rupee as *nazar* [present] any one could get his ear; even in a crowd one could catch his eye by holding up a rupee and crying out, . . . 'Maharajah, a petition!' He would pounce down like a hawk on the money, and, having appropriated it, would patiently hear out the petitioner." There is evidence that among ourselves in ancient days a like state of things existed. "We may readily believe," says Broom, referring to a statement of Lingard, "that few princes in those [Anglo-Saxon] days declined to exercise judicial functions when solicited by favorites, tempted by bribery, or stimulated by cupidity and avarice." And, on reading that in early Norman times "the first step in the process of obtaining redress was to sue out, or purchase, by paying the stated fees," the king's original writ, requiring the defendant to appear before him, we may suspect that the stated amount paid for this document represented what had originally been the present to the king for giving his judicial aid. There is support for this inference. Blackstone says, "Now indeed even the royal writs are held to be demandable of common right, on paying the usual fees:" implying a preceding time in which the granting of them was a matter of royal favor to be obtained by propitiation.

Naturally, then, when judicial and other functions come to be deputed, gifts will similarly be made to obtain the services of the functionaries; and these, originally voluntary, will become compulsory. Ancient records from the East yield evidence. Thus, in Amos ii. 6, it is implied that judges received presents; as are said to do the Turkish magistrates in the same regions down to our day: the assumption of the prophet, and of the modern observer, that this usage arose by a corruption, being one of those many cases in which the survival of a lower state is mistaken for the degradation of a higher state. Thus, again, in

early times in France judges received "spices" as a mark of gratitude from those who had won a cause. By 1369, if not before, these were converted into money; and in 1402 they were recognized as a due. The usage continued till the Revolution. In our own history the case of Bacon exemplifies not a special and late practice, but the survival of an old and usual one; local records show the habitual making of gifts to officers of justice and their attendants; and the facts are summed up in the statement that "no approach to a great man, a magistrate, or courtier, was ever made without the Oriental accompaniment—a gift." That in past times the propitiatory presents made to state-functionaries formed, in some cases, their entire revenues, is inferable from the fact that in the twelfth century the great offices of the royal household were sold; the implication being that the value of the presents received was great enough to make the places worth buying. Russia in early days seems to have exemplified the state in which the dependents and deputies of the ruler subsisted chiefly, if not wholly, on presents. Karamsin "repeats the observations of the travelers who visited Muscovy in the sixteenth century. 'Is it surprising,' say these strangers, 'that the grand-prince is rich? He neither gives money to his troops nor his embassadors; he even takes from these last all the costly things they bring back from foreign lands. . . . Nevertheless these men do not complain.'" Whence we must infer that, lacking wages and salaries from above, they lived on gifts from below. Moreover, we are at once enlightened respecting the existing state of things in Russia; for it becomes manifest that what we now call the bribes, which the miserably salaried officials require before performing their duties, are the representatives of the presents which formed their sole maintenance in times when they had no salaries. And the like may be inferred respecting Spain, of which Rose says: "From judge down to constable, bribery and corruption prevail. . . . There is this excuse, however, for the poor Spanish official. His government gives him no remuneration, and expects everything of him."

So natural has habit now made to us the payment of fixed sums for specified services, that, as usual, we assume this relation to have existed from the beginning. But when we read how, in little organized societies, such as that of the Bechuanas, the chiefs allow their attendants "a scanty portion of food or milk, and leave them to make up the deficiency by hunting or by digging up wild roots;" and how, in societies considerably more advanced, as Dahomey, "no officer under government is paid"—we are shown that originally the subordinates of the chief man, not officially supported, have to support themselves. And since their positions give them powers of injuring and benefiting subject persons—since, indeed, it is often only by their aid that the chief man can be invoked—there arises the same motive to propitiate them by presents that there does to propitiate by presents the chief man himself; whence the parallel growth of an income. The inference that the sus-

tentation of political officials begins in this way will presently find verification from its harmony with the inference more clearly to be established, that the sustentation of ecclesiastical officials thus originates.

Since at first the double of the dead man is conceived as being equally visible and tangible with the original, and as being no less liable to pain, cold, hunger, thirst; he is supposed similarly to want food, drink, clothing, etc., and to be similarly propitiated by providing them for him. So that, at the outset, presents to the dead differ from presents to the living neither in meaning nor motive.

All over the world, in lower forms of society, past and present, we find gifts to the dead paralleling gifts to the living. Food and drink are left with the unburied corpse by Papuans, Tahitians, Sandwich-Islanders, Malayans, Badagas, Karens, ancient Peruvians, Brazilians, etc. Food and drink are afterward carried to the grave in Africa, by the Sherbro people, the Loango people, the inland negroes, the Dahomans, etc.; throughout the Indian hills by Bhils, Santals, Kukis, etc.; in America, by Caribs, Chibchas, Mexicans; and the like usage was general among ancient races in the East. Clothes are periodically taken as presents to the dead by the Esquimaux. In Patagonia they annually open the sepulchral chambers and reclothe the dead; as did too the ancient Peruvians. When a potentate dies among the Congo people, the quantity of clothes given from time to time is so great "that, the first hut in which the body is deposited becoming too small, a second, a third, even to a sixth, increasing in dimensions, is placed over it." The motive for thus trying to please the dead man is the same as would have been the motive for trying to please the man while alive. When we read that a chief among the New Caledonians says to the ghost of his ancestor: "Compassionate father, here is some food for you; eat it; be kind to us on account of it;" or when the Veddah, calling by name a deceased relative, says: "Come and partake of this! Give us maintenance, as you did when living!" we see it to be undeniable that present-giving to the dead is the same as present-giving to the living, with the sole exception that the receiver is invisible.

Noting only that there is a like motive for a like propitiation of the undistinguished supernatural beings which primitive men suppose to be all around them—noting that whether it be in the fragments of bread and cake left for the elves, etc., by our Scandinavian ancestors, or in the eatables and drinkables which at their feasts the Dyaks place on the tops of the houses to feed the spirits, or in the small portions of food cast aside and of drink poured out for the ghosts before beginning their meals by various races throughout the world—let us go on to observe the developed present-making to the developed supernatural being. The things given and the motives for giving them remain the same; though the sameness is slightly disguised by the use of different words

—oblations to a deity and presents to a person. The original identity is well shown by the words of Guhl concerning the Greeks: "Gifts, as an old proverb says, determine the acts of gods and kings;" and it is equally well shown by a verse in the Psalms (lxxvi. 11): "Vow and pay unto the Lord your God: let all that be round about him bring presents unto him that ought to be feared." Moreover, we shall find a parallelism in the details that is extremely significant.

Food and drink, which constitute the earliest kind of propitiatory gift to a living person, and also the earliest kind of propitiatory gift to a ghost, remain everywhere the essential components of an oblation to a deity. As, where political power is evolving, the presents irregularly and then regularly sent to the chief, at first consist mainly of sustenance; so, where ancestor-worship, developing, has expanded the ghost into a god, the offerings, becoming habitual, have as elements common to them in all places and times, things to eat and drink. That this is so in low societies at large, no proof is needed; and that it is so in higher societies is also a familiar fact, though a fact ignored where its significance is most worthy to be marked. If a Zulu slays an ox to secure the good-will of his dead relative's ghost, who complains to him in a dream that he has not been fed —if among the Zulus this private act develops into a public act when a bullock is periodically killed as "a propitiatory offering to the spirit of the king's immediate ancestor"—we may, without impropriety, ask whether there do not thus arise such acts as those of an Egyptian king who by hecatombs of oxen hopes to please the ghost of his deified father; but it is not supposable that there was any kindred origin for the sacrifices of cattle to Jahveh, concerning which such elaborate directions are given in Leviticus. When we read that among the Greeks "it was customary to pay the same offices to the gods which men stand in need of—the temples were their houses, sacrifices their food, altars their tables"—it is permissible to observe the analogy between these presents of eatables made to gods and the presents of eatables made at graves to the dead, as being both derived from like presents made to the living; but that the presentation of meat, bread, fruits, and liquors, to Jahveh had a kindred derivation, is a thought not to be entertained—not even though we have a complete parallel between the cakes which Abraham bakes for the refreshment of the Lord when he comes to visit him in his tent on the plains of Mamre and the showbread kept on the altar and from time to time replaced by other bread fresh and hot. Here, however, recognizing these parallelisms, it may be added that though in later Hebrew times the original and gross interpretation of sacrifices became obscured, and though the primitive theory has since undergone gradual dissipation, yet the form survives. The offertory of our Church still retains the words, "accept our alms and oblations;" and at her coronation Queen Victoria offered on the altar, by the hands of the archbishop, "an altar-cloth of gold and an

ingot of gold," a sword, then bread and wine for the commmunion, then a purse of gold, followed by a prayer "to receive these oblations."

Looked at without bias, the evidence coming from all parts of the world thus proves that oblations are at first literally presents. Animals are given to kings, slain on graves, sacrificed in temples; cooked food is furnished to chiefs, laid on tombs, placed on altars; first-fruits are presented alike to living rulers, to dead rulers, to gods; here beer, here wine, here *chica*, is sent to a visible potentate and poured out as libation to an invisible deity; incense, in some places burned before distinguished persons, is burned before gods in various places; and, besides such consumable things, valuables of every kind, given to secure goodwill, are accumulated in the treasures of kings and in the temples of gods.

There is one further remark of moment. We saw that the present to the visible ruler was at first propitiatory because of its intrinsic worth, but came afterward to have an extrinsic propitiatory effect as implying loyalty. Similarly, the presents to the invisible ruler, primarily considered as directly useful, secondarily come to signify obedience; and their secondary meaning gives that ceremonial character to sacrifice which still survives.

And now we come upon a remakable sequence. As the present to the ruler eventually develops into political revenue, so the present to the god eventually develops into ecclesiastical revenue.

Let us set out with that earliest stage in which no definite organization, either political or ecclesiastical, exists, and in which the last is represented by the medicine-man, whose function is more that of expelling malicious ghosts than propitiating ghosts regarded as placable. At this stage the present to the supernatural being is often shared between him and those who propitiate him: the supposition, commonly vague and unsettled, being either that the supernatural being takes a substantial part of the food offered, or else that he feeds on its supposed spiritual essence while the votaries consume the material shell. The meaning of this, already indicated in the case of some other early usages, is that while the supernatural being is propitiated by the present of food, there is, by eating together, established between him and his propitiators a bond of union: implying protection on the one side and allegiance on the other. The primitive notion that the nature of a thing, inhering in all its parts, is acquired by those who consume it, and that therefore those who consume two parts of one thing acquire from it some nature in common which binds them together—that same notion which initiates the practice of forming a brotherhood by partaking of one another's blood, which instigates the funeral rite of blood-offering, which suggests the practices of the sorcerer, and which gives strength to the claims established by joining in the same meal, originates this prevalent usage of consuming part of the present of food made to the

ghost or the god. In some places the people at large participate in the offering; in some places the medicine-men or priests only; and in some places the last practice is habitual while the first is occasional, as in ancient Mexico, where communicants "who had partaken of the sacred food were engaged to serve the god during the subsequent year."

Here the fact which concerns us is that, from the presents thus used, there arises a maintenance for priests. When we read that the Chippewayan priests "are supported by voluntary contributions of provision," and that the priests of the Khonds have certain perquisites, and receive gifts, we vaguely see how in these rude societies there begins the support of a priesthood out of sacrifices; and in other cases we see this distinctly. Among the Kukis the priest, to pacify the angry deity who has made some one ill, takes, it may be a fowl, which he says the god requires, and, pouring its blood as an offering on the ground while muttering praises, "then deliberately sits down, roasts and eats the fowl, throws the refuse into the jungle, and returns home." In like manner the Battas of Sumatra sacrifice to the gods, horses, buffaloes, goats, dogs, fowls, "or whatever animal the wizard happens on that day to be most inclined to eat." And again we read that, by the Bustar tribes in the Mahadeva hills, Kodo Pen "is worshiped at a small heap of stones by every new-comer, through the oldest resident, with fowls, eggs, grain, and a few copper coins, which become the property of the officiating priest." More developed societies in Africa show us a kindred arrangement. Burton says that, in Dahomey, "those who have the 'cure of souls' receive no regular pay, but live well upon the benevolences of votaries;" and Forbes more specifically states that in their temples "small offerings are daily given by devotees, and removed by the priests." Similarly in the adjoining kingdom of Ashantee, "the revenue of the fetichmen is derived from the liberality of the people. A moiety of the offerings which are presented to the fetich belongs to the priests." It is the same in Polynesia. Ellis, describing the Tahitian doctor as almost invariably a priest, states that he received a fee, part of which was supposed to belong to the gods, before commencing operations. So, too, was it in the ancient states of America. A cross-examination, narrated by Oviedo, contains the passage:

"*Fr.* Do you offer anything else in your temples?

"*Ind.* Every one brings from his house what he wishes to offer—as fowls, fish, or maize, or other things—and the boys take it and put it inside the temple.

"*Fr.* Who eats the things thus offered?

"*Ind.* The father of the temple eats them, and what remains is eaten by the boys."

And then in Peru, where worship of the dead was a main occupation of the living, and where the ecclesiastical system was elaborately developed, the accumulated gifts to ghosts and gods had resulted in sacred estates, numerous and rich, out of which the priests of all kinds were

maintained. A parallel genesis is shown us by ancient historic peoples. Among the Greeks "the remains of the sacrifice are the priests' fees," and "all that served the gods were maintained by the sacrifices and other holy offerings." Nor was it otherwise with the Hebrews. In Leviticus ii. 10 we read, "And that which is left of the meat-offering shall be Aaron's and his sons'" (the appointed priests); and other passages entitle the priest to the skin of the offering, and to the whole of the baked and fried offering. Neither does the history of early Christianity fail to exhibit the like development. "In the first ages of the Church, those *deposita pietatis* which are mentioned by Tertullian were all voluntary oblations." Afterward "a more fixed maintenance was necessary for the clergy; but still oblations were made by the people. . . . These oblations [defined as 'whatever religious Christians offered to God and the Church'], which were at first voluntary, became afterward, by continual payment, due by custom." In mediæval times a further stage in the transition is shown us: "Besides what was necessary for the communion of priests and laymen, and that which was intended for eulogies, it was at first the usage to offer all sorts of presents, which at a later date were taken to the bishop's house and ceased to be brought to the church." And then by continuation and enlargement of such donations, growing into bequests, nominally to God and practically to the Church, there grew up ecclesiastical revenues.

Doubtless sundry readers have made on the foregoing statements the running criticism that they represent all presents as made by inferiors to propitiate superiors; and that they ignore the presents having no such purpose, which are made by superiors to inferiors. These, though they do not enter into what can be called ceremonial government, must be noticed. The contrast between the two kinds of presents, in meaning, is well recognized where present-making is much elaborated, as in China. "At or after the customary visits between superiors and inferiors, an interchange of presents takes place: but those from the former are bestowed as *donations*, while the latter are received as *offerings;* these being the Chinese terms for such presents as pass between the emperor and foreign princes."

Naturally it happens that as the power of the political head develops, until at length, with little or no check, he assumes universal ownership, there results a state in which he finds it needful to give back to his dependents and subjects part of that which he has monopolized. And having been originally subordinated by giving, these are now, to a certain extent, further subordinated by receiving. People of whom it can be said, as of the Kukis, that "all the property they possess is by simple sufferance of the rajah," or people who, like the Dahomans, are owned in body and estate by their king, are obviously so conditioned that property having flowed in excess to the political centre must flow down again from lack of other use; and hence in Dahomey, though no

state-functionary is paid, the king gives his ministers and officers royal bounty. Without traveling further a-field for illustrations, it will suffice if we note these relations of causes and effects from early European times downward. Of the ancient Germans, Tacitus says: "The chief must show his liberality, and the follower expects it. He demands at one time this war-horse; at another, that victorious lance imbrued with the enemy's blood. The prince's table, however inelegant, must always be plentiful; it is the only pay of his followers." That is, a monopolizing supremacy had, as its sequence, gratuities to dependents. Mediæval times were characterized by modified forms of the same system. In the thirteenth century, "in order that the princes of the blood, the whole royal house, the great officers of the crown, and those . . . of the king's household, should appear with distinction, the kings gave them dresses according to the rank they held and suitably to the season at which these solemn courts were celebrated. These dresses were called liveries because they were delivered," as the king's free gifts; a statement showing clearly how the reception of such presents signified subordination. Down to the fifteenth century on a feast-day, the Duke of Burgundy gave to the knights and nobles of his household "presents of jewels and rich gifts . . . according to the custom of that day;" such presents, in addition to maintenance, house-room, and official dresses for themselves and their servants, probably constituting the sole acknowledgment for their attendance. It need scarcely be added that, throughout the same stages of progress in Europe, the scattering of *largesse* to the people by kings, dukes, and nobles, was similarly a concomitant of that servile position in which such return as they got for their labor in addition to daily sustenance was in the shape of gratuities rather than in the shape of wages. Moreover, we still have, down to our own day, in vails and Christmas-boxes to servants, etc., the remnants of a system under which fixed remuneration was eked out by gifts—a system itself sequent upon the earlier system under which gifts formed the only remuneration.

Thus it becomes tolerably clear that, while from presents offered by subject persons there eventually develop tribute, taxes, and fees, from donations made by ruling persons there eventually develop salaries.

Something must be added concerning presents passing between those who do not stand in acknowledged relations of superior and inferior. Consideration of these carries us back to the primitive form of present-making, as it occurs between strangers or members of alien societies; and, on looking at some of the facts, there is suggested a question of much interest: whether from the propitiatory gift made under these circumstances there does not originate another important kind of social action? Barter is not, as we are apt to suppose, universally understood. Cook, speaking of his failure to make any exchange of articles with the Australians of his day, says, "They had, indeed, no idea of

traffic." And other statements suggest that, when exchange begins, there is little idea of equivalence between the things given and received. Speaking of the Ostiaks, who supplied them "with plenty of fish and wild-fowl," Bell says, "Give them only a little tobacco and a dram of brandy, and they ask no more, not knowing the use of money." Remembering that at first no means of measuring values exists, and that the conception of equality of value has to grow by use, it seems not impossible that mutual propitiation by gifts was the act from which barter arose; the expectation that the present received would be of like worth with that given being gradually established, and the exchanged articles simultaneously losing the character of presents. One may, indeed, see the intimate connection between the two in the familiar cases, instanced at the outset, of presents from European travelers to native chiefs; as where Mungo Park writes, "Presented Mansa Kussan [the chief man of Julifunda] with some amber, coral, and scarlet, with which he appeared to be perfectly satisfied, and sent a bullock in return." Such transactions show us both the original meaning of the initial present as propitiatory, and the idea that the responsive present should have an approximately-like value, implying informal barter.

Leaving this speculation, however, we have here to note the way in which the propitiatory present becomes a social observance. Like every other kind of ceremony which begins as an effort to gain the good-will of some feared being, visible or invisible, gift-making descends through successive stages, until it becomes an act of civility between those who, while not actually subordinate one to the other, please one another by simulating subordination. That along with the original form of it, signifying allegiance to a chief or king, there goes the spread of it as a means of insuring the friendship of powerful persons in general, we see in ancient Peru, where, as already said, "no one approached Atahuallpa without bringing a present in token of submission," and where also "the Indians . . . never thought of approaching a superior without bringing a present." And then in Yucatan the usage extended to equals. "At their visits the Indians always carry with them presents to be given away, according to their position; those visited respond by another gift." In Japan, so rigorously ceremonious, the stages of the descent are well shown: there are the periodic presents to the mikado, expressive of loyalty; there is the fact named by Mitford that "the giving of presents from inferiors to superiors is a common custom;" and there is the further fact he names that "it is customary on the occasion of a first visit to a house to carry a present to the owner, who gives something of equal value on returning the visit." Among other peoples we see this mutual propitiation between equals taking other forms. Markham, writing of Himalayan people, states that exchanging caps is "as certain a mark of friendship in the hills as two chiefs in the plains exchanging turbans." And, referring more especially to the Iroquois, Morgan says, "Indian nations, after treating,

always exchanged belts, which were not only the ratification, but the memorandum of the compact."

How gift-making, first developed into a ceremony by fear of the ruler, and made to take a wider range by fear of the strong or the influential, is eventually rendered general by fear of equals who may prove enemies if they are passed over when others are propitiated, we may gather from European history. Thus, in Rome, "all the world gave or received New-Year's gifts." Clients gave them to their patrons; all the Romans gave them to Augustus. "He was seated in the entrance-hall of his house; they defiled before him, and every citizen, holding his offering in his hand, laid it, when passing, at the feet of that terrestrial god. These gifts consisted in silver money, and the sovereign gave back a sum equal or superior to their presents." Because of its association with pagan institutions, this custom, surviving into Christian times, was condemned by the Church. In 578 the Council of Auxerre forbade New-Year's gifts, which it characterized in strong words. Ives, of Chartres, says, "There are some who accept from others, and themselves give, devilish New-Year's gifts." In the twelfth century, Maurice, Bishop of Paris, preached against bad people who "put their faith in presents, and say that none will remain rich during the year if he has not had a gift on New-Year's-day." Notwithstanding ecclesiastical interdicts, however, the custom survived through the middle ages down to modern times; until now priests themselves, as well as others, participate in this usage of mutual propitiation. Moreover, there have simultaneously developed kindred periodic ceremonies; such as, in France, the giving of Easter-eggs. And present-makings of these kinds have undergone changes like those which we traced in other kinds of present-makings: beginning as moderate and voluntary, the presents have become extravagant and in a measure compulsory.

It thus appears that, spontaneously made among primitive men by one member of a tribe to another, or to an alien whose good-will is desired, the gift becomes, as society evolves, the originator of many things.

To the political head, as his power grows, the making of presents is prompted partly by fear of him and partly by the wish for his aid; and the presents made, at first propitiatory only from their intrinsic worth, come presently to be propitiatory as expressions of loyalty; from the last of which there results present-giving as a ceremonial, and from the first of which there results present-giving as tribute, eventually developing into taxes. Simultaneously, the supplies of food, etc., placed on the grave of the dead man to propitiate his ghost, developing into larger and repeated offerings at the grave of the distinguished dead man, and becoming at length sacrifices on the altar of the god, differentiate in an analogous way. The present of meat, drink, or clothes, at first supposed to propitiate because actually useful to the ghost or the

god, becomes, by implication, significant of allegiance. Hence, making the gift grows into an act of worship irrespective of the value of the thing given; while in virtue of its substantial worth, the gift, affording sustenance to the priest, makes possible the agency by which the worship is conducted; from the oblation originate church revenues.

Thus we unexpectedly come upon further proof that the control of ceremony precedes the political and ecclesiastical controls; since it appears that from actions which the first initiates eventually result the funds by which the others are maintained.

When we ask what relations present-giving has to different social types, we note, in the first place, that there is little of it in simple societies, where chieftainship does not exist, or is unstable. In wandering, headless tribes it manifestly cannot become established and systematized; nor in simple settled tribes of which the headships are nominal. But we find it to prevail in compound and doubly-compound societies, as throughout the semi-civilized states of Africa, those of Polynesia, those of ancient America, etc., where the presence of stable headships, primary and secondary, gives both the opportunity and the motive; and, recognizing this truth, we are led to recognize the deeper truth that present-making, while but indirectly related to the social type as simple or compound, is directly related to it as more or less militant in organization. The desire to propitiate must be great in proportion as the person to be propitiated is feared; and therefore the conquering chief, and still more the king who has made himself, by force of arms, ruler over many chiefs, is one whose good-will is most anxiously sought by acts which simultaneously gratify his avarice and express submission. Hence, then, the fact that the ceremony of making gifts to the ruler prevails most in societies that are either actually militant, or in which chronic militancy during past times has evolved the despotic government appropriate to it. Hence the fact that throughout the East, where this social type exists everywhere, the making of presents to those in authority is everywhere imperative. Hence the fact that in early European ages, while the social activities were militant and the structures corresponded, loyal presents to kings from individuals and corporate bodies were universal; while *largesse* from superiors to inferiors, also growing out of that state of complete dependence which accompanied militancy, was common.

The like connection holds with the custom of making presents to deities. In the extinct militant states of the New World, sacrifices to gods were perpetual, and their shrines were being ever enriched by deposited valuables. Papyri, wall-paintings, and sculptures, show us that among ancient Eastern nations, highly militant in their activities and types of structure, the oblations to deities were large and continual; and that vast amounts of property were devoted to making glorious the places where they were worshiped. So, too, in early militant times throughout Europe, gifts to God and the Church were

more general and extensive than they have become in later industrial times. It is observable, too, how, even now, that representative of the primitive oblation which we still have in the bread and wine of the mass and the sacrament (offered to God before being consumed by communicants) recurs less frequently here than in Catholic societies, which are relatively more militant in type of organization; while the offering of incense, which is one of the primitive forms of sacrifice among various peoples, and survives in the Catholic service, has disappeared from the authorized service in England. Nor in our own society do we fail to trace a kindred contrast; for, while within the Established Church, which forms part of that regulative structure developed by militancy, sacrificial observances still continue, they have ceased among those most unecclesiastical of dissenters, the Quakers; who, absolutely unmilitant, show us also by the absence of an established priesthood, and by the democratic form of their government, the type of organization most remote from militancy and most characteristic of industrialism.

The like holds even with the custom of present-giving for purposes of social propitiation. We see this on comparing European nations, which, otherwise much upon a par in their stages of progress, differ in the degrees to which industrialism has qualified militancy. In Germany, where periodic making of gifts among relatives and friends is a universal obligation, and in France, where the burden similarly entailed is so onerous that at Christmas and Easter people not unfrequently leave home to escape it, this social usage survives in greater strength than in England, less militant in organization.

Of this kind of ceremony, then, as of the kinds already dealt with, we may say that, taking shape with the establishment of that political headship which militancy produces, it develops with the development of the militant type of social structure, and declines with the development of the industrial type.

HOW SOUND AND WORDS ARE PRODUCED.

By GEORGE M. SHAW.

THE recent appearance of those remarkable devices the telephone and the phonograph has given such a new interest to the general subject of voice, music, and sound, and the conditions and mechanisms by which they are produced, that a familiar explanation of some of the points involved may be useful at the present time.

Prof. Tyndall, in his work "On Sound," speaking of a tremendous powder-explosion which occurred at Erith, England, in 1864, shattering the windows on every side, though the village was some miles from the magazine, says: "Lead sashes were employed in Erith church, and

these being in some degree flexible, enabled the windows to yield to pressure without much fracture of the glass. Every window in the church, front and back, was bent *inward*. In fact, as the sound-wave reached the church, it separated right and left, and for a moment the edifice was clasped by a girdle of intensely-compressed air, which forced all its windows inward."

Now, was this "sound-wave" of compressed air, that struck the church, a wind-storm from the place of explosion? If not, whence all this force? That there was no wind is plain from the fact no dust was raised, nor a leaf stirred from its place. We must look for another explanation.

Suppose that, in the middle of a closely-packed crowd, "room" were suddenly made by pushing back the by-standers. These, thus suddenly losing their balance, would fall back on those behind them, and these in turn on others, and so on to the outsiders. It is easy to see that each one would recover his own balance by pushing against the one behind him, and so the fall-back movement would be seen to pass like a wave through the crowd, each one passing it on as it reached him. In like manner, the push of the expanding gases, at the explosion, was transmitted to the church, the intervening air only passing the push along. If the windows of the church had been elastic, they would have swayed with the air; as it was, they were pushed in, but had no back-spring.

The impulse which struck the church struck many ears in the same way, but their drums taking up the air-push and its back-snap, sent it to the brain, where it was put down as a tremendous sound. Sound, then, is only the beating of air-waves in the ear.

Now, a sound is either a noise or a musical tone. We take a noise to be the blow of a single wave, or an irregular succession of waves striking the ear, while a tone is the sound made by the beating of the same kind of a wave, at regular intervals, in such rapid succession as to form a sound-blend in the ear akin to the spoke-blend presented to the eye by the spokes of a fast-turning wheel.

We have divided sound into *noise* and *musical tones*, and have spoken of a tone, distinguished from noise, as being a sound-blend

FIG. 1.

made in the ear by the beating of the same kind of a wave, at regular intervals, in rapid succession. Let us prove this. We will strike middle C on a piano. We get a musical tone from its string, which is set a-vibrating, as shown in Fig. 1. But how shall we determine the num-

ber of vibrations, for we cannot begin to count them? We will take a tuning-fork, *D*, Fig. 2, that gives the same tone as middle C, thus having the same number of vibrations, and attach with a bristle fastened to one prong by a little wax. This will trace the vibrations, *P*, on the smoked paper *L*. The wave-forms of the marking, counted along either one side, indicate the number of vibrations. We count these wave-forms, and divide by the number of seconds the vibration lasted, and we have the number of vibrations per second corresponding to the tone of the fork. In this case we find "middle C" to vibrate 264 times in a second. In

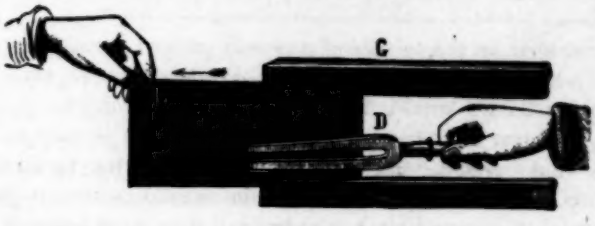

FIG. 2.

the same way, we find D to vibrate 297; E, 330; F, 352; G, 396; A, 440; B, 495; and C, again, 528 times per second, just double of "middle C" below. In the same way each of the other tones doubles its vibrations going up, and halves them going down. Thus, from the first A of the bass of a seven-octave piano, to the last A of the treble, we have a range of from 27 vibrations, or pulses, per second to as many as 3,520. The number of vibrations is the same for the same note on any instrument.

We have thus proved, in a simple way, that a musical tone is produced by rapid, *regular* vibration, as shown by the marking—the air-waves, set up by the vibration, seeming to blend in the ear in a manner similar to that in which the vibrations of the string blend to the eye, which makes the tone seem continuous. In this experiment we notice that tones are high or low, according to the number of their vibrations—the higher the tone the greater the number of its vibrations per second. Again, we observe that we can make the same tone loud or soft, without making it higher or lower. We notice that loudness is obtained by striking with greater force, making the string or fork swing farther from side to side, but still swing the same number of times in a second. This force of the swing is given to the air, and carried to the ear, beating it with greater violence than before, but still only the same number of times a second. This width of swing, which makes the loudness of a sound, by a greater compression in the air-wave, is called the *amplitude of vibration*, and corresponds to the height of water-waves, where the amplitude is up and down. In water, the greater the force the higher are the waves. Now, let us turn to the sound-wave in the air, which we will study by the aid of Fig. 3. Here we take an ordinary A tuning-

fork, having an elasticity of 440 vibrations per second, and set it a-vibrating. The prong of the fork, in moving from *a* to *a'*, pushes the layer of air in front of it, which, in its endeavor to recover from this huddling, pushes against the next layer, which is thus in its turn compressed, the compression or push passing in this way, from layer to layer, through the air—the wider the swing of the prong the greater the compression in the air, and the louder the sound; meanwhile the prong moves back from *a'*

FIG. 3.

to *a*, causing a vacuum, which is instantly filled up by the return of the air which it had just pushed away. But the fork now swings back to *a''*, causing the layer of air not only to return to its ordinary density at *a*, but causing it to expand, in order to fill up the vacuum from *a* *a''*, thus producing a rarefaction, or stretch, in the air, which draws back on every other layer, causing a pulse of rarefaction to follow every pulse of compression; in other words, causing a stretch-gap to follow every push. A clear idea of this may be had by again using our illustration of a crowd: the place where some are just falling back on those behind them illustrates the wave of compression, while the gap between those falling back and those who have just recovered their balance illustrates the wave of rarefaction which follows it. An air-wave is made up of a compression and a rarefaction—a push and a stretch—the two being produced in one vibration of the prong, the compression by the motion from *a* to *a'*, and the rarefaction by the reactive motion from *a* to *a''*. On its way back to *a*, the prong lets up on the stretch, and goes on to *a'* with another push, and so on as long as it vibrates. These compressions and rarefactions, represented in the figure by its shadows and lights, correspond to the crests and hollows of water-waves.

In water we measure the length of waves (that is, the distance between them) from swell to swell. Sound-waves are measured from huddle to huddle. Now, how are we going to measure this? Let us take the case of water. If we knew that in 100 yards of water there were 100 equal waves, we would know that each wave was one yard in length—that is, that the wave-swells were thus far apart; or, if there were 50, each wave would stretch two yards. We would find the length of wave by dividing the distance covered by the number of waves stretched over it. The length of sound-waves is measured in the same way. We will measure the length, or distance apart, of the waves of our A-fork experiment. Sound travels, in round numbers,

1,100 feet in a second. Now, our A-fork, vibrating 440 times a second, sets 440 sound-waves in motion in a second, so that, at the end of a second, there would be 440 air-waves afloat, and the first one would have reached a distance of 1,100 feet away. Now, there being 440 equal air-waves in 1,100 feet, how far apart are they—in other words, how long is each wave? Dividing the 1,100 feet by the 440 waves, we get two and a half feet, or 30 inches, as the length of the air-waves of the first A-tone above "middle C"—the A-string of a violin. In the same way we find that the *first* A of the bass of our piano produces air-waves about *forty feet* in length, while the waves of the last A of the treble are not quite *four inches* long. We find the length of the air-waves of any musical note—that is, the distance apart of the *pushes* in the air—by dividing 1,100 feet, the distance which the waves would cover in a second, by the number of the note-vibrations per second, which represents the number of air-waves it would make in that time.

One thing we notice in all sounds, and that is their character, or peculiarity. They may be as near alike as they can be made, but each different kind will have something about it which distinguishes it from every other, and it is by this means that we distinguish different instruments or voices. The cause of this is the peculiar shape in which the wave comes from different sources, a sort of individual stamp by which a sound carries the telltale mark of its maker. These different stamps or trimmings of air-waves may be illustrated in Fig. 4, and will

FIG. 4.

be *explained* presently. The heavings represent the compressions, and the hollows the rarefactions, in the air. Let *A* represent the wave-form of the purely ideal tone of the note A with no stamp or quality given to it. *B* might represent the wave-form given it by a piano; and *C*, that given to it by a violin. In each case the wave-length, or distance between swells, and therefore *pitch* of tone, and the amplitude, or size of swells, and therefore *loudness* of tone, are the same; the only difference is, that the last two tone-waves seem to be trimmed with feather-waves, so to speak, the trimming varying with the source of the wave.

A simple noise being a sound-wave, has its wave-form or make-mark. The blending of many such would produce a tone in that likeness; hence, a musical note is a blending of like noises, and every noise is really the first wave, the key-note of a musical tone. Take the ringing of a door-bell. Here the ear hears not only a musical tone, a sound-blend, in the *ring* of the bell, but also the noise of the clapper's clang, clang, clang. The vibrations of the bell throw the air into musical waves, shown in Fig. 5, while a huge clang-wave will sweep

FIG. 5.

along among the *ring*-waves every time the clapper strikes. If these clang-waves were to come along fast enough to blend, and at regular intervals, they would produce a tone of their own. The clanging of the clapper would not be a noise, but a deep tone, perhaps making a chord with the *ring*-tone. But, as it is, the clang-waves come irregularly and slowly, and only a noise is the result. The clang-wave is not represented in the figure, but may be easily imagined. From this we see that different sets of air-waves can move along together, and, though they should conglomerate, the ear can single them out. And now we can explain the peculiar character of different sounds, represented by the different forms of waves in Fig. 4. If the string in Fig. 1 would really vibrate in a clean sweep as it appears to, it would make

FIG. 6.

a smooth wave-form, like *A* in Fig. 4; but, while it vibrates as a whole, in starting the vibration of the string the sudden jerk on it will run along the string in a sort of wabble-wave to its ends and back again, as long as the string vibrates.

These wabble-waves, in passing each other as they run back and forth on the string in opposite ways, will form stand-still crossing

points at distances apart corresponding to the length of the wabble-waves; thus dividing the string into vibrating parts, as in Fig. 6.

These make their own little swift air-waves, while the whole string is making its large and comparatively slow ones, and thus produce what are called overtones—waves within waves. These form the feather-wave trimming spoken of, and shown in Fig. 4. These over-vibrations chord

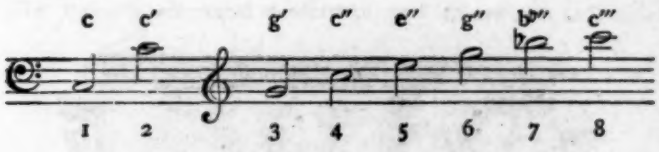

Fig. 7.

or harmonize with the vibrations of the whole string, and are drowned in it, forming a conglomerate air-wave. They are two, three, four, five, six, seven, eight, etc., times the vibration of the whole string, and it is according to which of these over-vibrations is the fullest, that the sound takes its peculiar quality. Sounds without overtones are dull; with too many, harsh and grating; and, with the first six in fair proportion, are rich and sweet. Fig. 7 represents in musical language the overtones of the note C of 132 vibrations; number 1 being the whole string, the other numbers denoting the overtones up to the eighth, the first six being those that give richness to the tone, and of these, one or another being the most prominent according to the source from which the note comes.

We have said that the overtones are drowned in the tone—only stamping or trimming it, but they can be picked out. Let us see now how we can pick these overtones out of the conglomerate.

Fig. 8.

It is found that a column of air one-fourth the wave-length, of any note's air-waves, will resound to that note and to no other. Let us take our A-fork again with 440 vibrations per second, making a wave-length of 30 inches, and when vibrating hold it over a tall jar as in Fig. 8. The column of air may not be the right length. By pouring in water a point will be reached at which the jar will burst into the tone A with the fork. By pouring in more water it stops. A certain length only will resound A. Measur-

ing the resounding column of air, from the water to the top of the jar, we find it to be 7½ inches, one-fourth the length of the A-wave. Now, by making a resounder of this size, with an ear-opening in the bottom, we shall have an instrument that will pick out A every time from a sea of sound. This resonator is shown in Fig. 9; and Fig. 10 shows another form of the same instrument. Resonators tuned to the different

FIG. 9.

notes are made, and by their aid any sound can be analyzed, and each overtone brought out like the throbbing of a single string.

In this way it has been found that the peculiar character, or stamp, of any sound depends on its overtones, and furthermore on exactly what ones, so that by reproducing them any sound can be imitated. Of all sounds those of the human voice are the sweetest. None others are so rich in harmonic overtones, and this brings us to Words.

The vocal mechanism is made in two pieces. One, a wonderful musical instrument with only *one vibrator*—the vocal chords, Fig. 11—which can tune itself at once to any note. The other, the mouth, as an echo-cave or resonator, no less wonderful in its power of forming itself to resound the harmonics of the vocal tones. This gives the

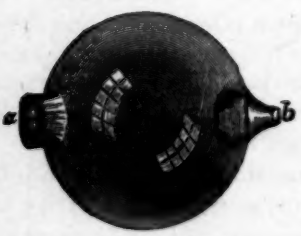

FIG 10.

FIG. 11.

voice its power of imitating any sound within its reach. We will analyze the voice.

Let the vocal chords sing or vibrate any note, and by merely changing the hollow of the mouth the purely musical sound will turn into what are called the *vowel*-sounds of speech, the closest position of the mouth making it *ee*, the deepest *oo*. Why is this, since the musical note is the same in each? It is because the different positions of the mouth resound to different overtones. While some vowel is sung we

hold different resonators to the ear until we find the overtones. They must be the cause of the *vowelizing* of the tone sung. To prove it we take a tuning-fork vibrating the note of that vowel's overtone as found by the resonator, and, holding it in front of the mouth, we shape the mouth until it resounds to the tuning-fork. Keeping the mouth in this position, we sound the vocal chords, and the result is the vowel, thus proving that that particular overtone is its stamp. And so each vowel-sound is found to be due only to different overtones of the tone sung, brought out by the resonance of the mouth. Mixing in some of the other overtones forms the distinguishing peculiarity of individual voices.

Vowel-sounds, then, are really an exquisite musical harmony, being nothing but "chords" of the tone with its different overtones, different "chords" making different vowels. The common musical scale is derived from a tone and its overtones, by making, on separate strings, full tones corresponding to the overtones of some fundamental string-tone. That which produces a "chord" in music, where the harmony is made by full tones, would produce a vowel if the main tone only were full, and the "chording" tones overtones. When, then, a vowel is sung, high or low, it is still the same vowel at a different pitch—that is, the same "chord" in another key. But "chords" are music, and music means air-waves, so that vowels are musical air-waves. But vowels alone, which are only musical tones, will not make speech. Yet, by breaking into the vowel-tone with certain expressive noises called consonants, we can give the vowel-tone such a turn as to make its motion a copy of a motion of sensation, which, reaching the mysterious mechanism of an ear, will be changed back into a sensation.

It seems strange that words should be nothing but music broken up by different expressive noises, but we all know how differently we are affected by different noises. And in music it is recognized that different keys produce different effects; certain keys better than others, exciting certain emotions. But what are certain keys but certain vibrations, and these vibrations but certain motions? And, again, what are emotions but *derived motions*, which again are but vibrations?

To illustrate, let us follow the transmutations of a sensation. Let a "consciousness" be excited. That means motion, and from that tense focus the emotion rushes through the nerves, losing in intensity as it gains more room—that is, the more nerves there are that are set in vibration the slower the vibration becomes—music still and in the same key, but lower down the scale. Suppose the key of the emotion or sensation to be the one that moves the hand, then the hand will act. Suppose the key to be the one whose "chords" the vocal mechanism plays in, then that will take up the nerve-waves, which will thus be transformed into air-waves, but who can tell how many octaves below the pitch of the sensation-waves in the nerves? The waves have passed as through a lens, and been magnified like mites in a magic-lantern. Suppose the sensation to have made one speak the word "hope." We

cannot explore the nerve-waves, but, projected in the air, they become a picture that we can study. First there is the rough breathing or tremor *h*, then the mouth tunes itself for the musical tone *o*. Suppose the *o* to be made in a man's voice at a pitch A, below middle C. The *o*-making overtone is its octave overtone or second, which in this case will be A above middle C, the pitch to which the mouth will resound. Besides this prominent overtone, *o* has some feeble *third* and *fourth* overtones, and for the *personal* peculiarity say a little *fifth*. What is

FIG. 12.

this *o*, then? A tone-vibration of 220 per second, frilled with overtone vibrations of 440, 660, 880, and 1,100 *per second*. In the air, on its way to an ear, this *o* is a matter of air-waves 5 feet in length, filled in with waves of 30, 20, 15, and 10 inches in length, and—let us be thankful that we do not have to understand *o* before we can exclaim it. Following this, the mouth suddenly shuts up and pushes off the vowel-ripples with a noisy billow *p*. Fig. 12 will give an idea of the "hope" waves going through the air, end-foremost, of course, as they were spoken. And so words follow each other in sets of waves like the above, with rests between the sets made by the pauses between words.

Now, how far will these waves be loud enough to be heard—that is, how long will they keep strong enough to beat the drum-head of an ear? The farther they go the more they spread, and the weaker they become. A strong voice may be heard at an eighth of a mile, or about 700 feet. As sound travels 1,100 feet per second, it follows that, in less than a second after being spoken, the waves become too weak to make words. Let us be quick, then, to find what they are saying. Sun-waves, spreading from a focus, may be brought again to a focus by condensing them with a lens. So the

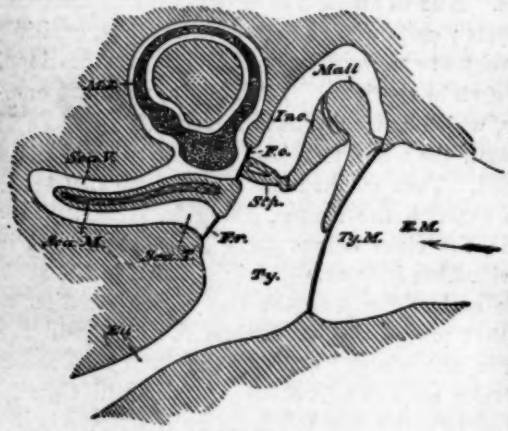

FIG. 13.

sensation-waves, which spread from a focus, may be brought again to a focus by condensing them with an *ear* (Fig. 12). Here, across a little echo-cave, is hung a curtain, *Ty. M.*, which is blown in and out as each air-wave beats against it; and, though the air-waves vary from 40 feet to 4 inches apart, they jump the distance quickly, and this curtain, taking an exact copy of each, in vibrations less than the thousandth part of an inch, sends them, through the tapping bones, *Mall.*, *Stp.*, to an inside curtain, *F.o.*, where they are condensed again, and thrown through a liquid which fills the hollow inside of it. Here three thousand tuned nerves take up, each, its own acchording waves, and bear them to the brain; and thus the wild waves of an emotion passed from one "consciousness" to another in less than a second, proving that the "quickness of thought" is no metaphor. Through pipes, the *sound* of the voice may be heard nearly four miles, and conversation carried on at nearly a mile. Through the wire of the *telephone*, which has become literally the "thread of a conversation," sound, with all its qualities, is conveyed hundreds of miles, as we have already shown in a former article.

THE SCIENTIFIC STUDY OF HUMAN TESTIMONY.

By GEORGE M. BEARD, M. D.

I.

"Of what account are the most venerated opinions, if they be untrue? At best they are only venerable delusions."—Sir William Hamilton.

ABOUT two years ago I chanced to call on an educated professional man, who was much interested in the subject of delusions. He said, "I have been long wishing to see you, in order to get an explanation of some strange things that have happened under my observation." I inquired what these strange things were. He replied, as usual in such cases, by giving a detailed account of certain performances of a well-known trickster, to which I listened as politely as I could, and he concluded with this conundrum: "Now, how do you explain that?" I replied: "I do not know what happened, for there was no expert there to report. If I knew what happened, I could very likely explain it, for a knowledge of what happened would itself be the explanation." "But I have just told you what happened," he interposed, somewhat excitedly. "My wife and I both were there, and we saw it all, with our own eyes. Can't we trust our senses?" "Trust our senses?" I replied; "not at all. In science we never trust our senses." My friend was as much astonished and indignant as though he had been personally insulted, and I felt it to be prudent to withdraw from the house.

Quite recently, while conversing with a scholar and logician of far more than usual powers, we chanced to talk of the alleged feats of levitation, and he asked me how they were to be explained. I told him that there was no evidence that they had ever occurred; and that it was known deductively, by the established laws of physiology, that they had not and could not occur. I furthermore stated that claims of this sort could be and should be only studied by experts; that experiments with living human beings could only be conducted by experts in cerebro-physiology, and that probably there were not half a dozen persons in the world capable of making experiments of that kind. My friend failed to see the justness of this view, and confessed himself unable to understand how so simple a matter as the rising of a body in a room could not be settled by the eyes of any honest, well-balanced man. "Why," said he, "if a dozen George Washingtons should testify that they had all seen a man rise in the air, I should be compelled, by the rules of evidence, to believe them. What is the need of an expert in a matter of simple eyesight and common honesty?"

I refer to these conversational experiences, because they represent, in a concrete form, the present attitude of scholars and logicians toward the principles of evidence.

That these instances are not exceptional is proved by the literature of science, of religion, of logic, and of law, in all of which departments the subject of human testimony is more or less discussed. Neither in Whewell's "History of the Inductive Sciences" nor in Jevons's "Principles of Science" do we find a correct or thorough analysis of human testimony, on which all science depends; by these authors, as much as by religious, apologetic writers, it is assumed that the senses are to be trusted. In the department of logic we do not find, either in Mill or Hamilton, any attempt even to build up a science of human testimony which must everywhere constitute the premises of reasoning, and by which the results of reasoning are to be determined. Constantly Sir William Hamilton reiterates that logic deals only with the forms of reasoning, and is not at all responsible for the premises; but nowhere does he point out, in a satisfactory manner, the principles on which premises are to be obtained. It is true that Bacon, under the fantastic titles, "Idols of the Tribe," "Idols of the Den," "Idols of the Forum," and "Idols of the Theatre," first pointed out some of the more obvious sources of error, and writers on logic repeat his views; but other sources of error, equally important but far more subtile, are not referred to even in the most recent treatises on reasoning. Students of science, particularly of physiological science, and, above all, experimenters with living human beings, must either trust to their instincts, as many do, or find out for themselves, by study and experience, the special sources of error in researches of this character, and guard against them.

Coming to law, we find that Prof. Greenleaf, one of the most valued writers on the principles of evidence, says that "the credit due to the

testimony of witnesses depends upon, firstly, their honesty; secondly, their ability; thirdly, their number and the consistency of their testimony; fourthly, the conformity of their testimony with experience; and, fifthly, the coincidence of their testimony with collateral circumstances." Here we observe that honesty is placed before ability, while under ability no distinction is drawn between general and special ability—in other words, between the non-expert and the expert. In the formulated statement of the principles of evidence from which this extract is taken, not only is there no distinction made between expert and non-expert, but no recognition of the fact that the senses of honest and unbiased witnesses may be, through a variety of causes, untrustworthy.

The mistakes in the administration of justice are already numerous, but they would have been more so if judges and juries had not instinctively rejected the principles of evidence thus taught by the highest authorities in jurisprudence.

All modern science is the product of exclusively expert evidence: until an expert develops, there can indeed be no science; and yet, one may look in vain through all the authors on logic for a satisfactory definition of an expert, or for any detailed arrangement of tests by which expertness is to be estimated.

The subject of human testimony has, in short, never been scientifically studied; practical rules for the guidance of those who employ it are all that either logic or law has yet given to the world. As some of these practical rules are based on incorrect assumptions in regard to the value of human testimony, they frequently lead to serious error, and, as they fail to draw just distinctions between the good and bad in evidence, or to give special suggestions for special cases, they are oftentimes of no assistance whatever. This criticism is not made in the way of complaint, for only within the past few years has it been possible to even begin the scientific study of human testimony, while nearly all of our writers on this subject belong to the past generations,[1] and the few later authors mostly copy the errors and imperfections of their predecessors.

Human testimony comes from the human brain: the scientific study of human testimony is only possible through a knowledge of the human brain in health and disease, and is therefore a department of cerebro-physiology and pathology. Only recently have the laws of cerebro-physiology and pathology been sufficiently understood, even by

[1] It may perhaps be objected to this statement that many so-called apologetic and skeptical writings are of recent date; but writers of this class, on both sides, as well as the controversialists on the spiritualism question, assume, without discussion, the principles of evidence as taught in logical and legal text-books. On every page of the writings of the Tübingen school, as De Wette, Bauer, Paulus, Strauss, as well as of their opponents in Germany and in the Bampton Lectures, we find evidences of the imperative need of a reconstruction of the principles of evidence. This need is fully admitted by the late Mr. Mozley, in the preface to the third edition of his "Lectures on Miracles."

the very few who cultivate that specialty, to enable them to formulate principles for the scientific study of that most important product of the human brain—human testimony. If, then, Bacon and Descartes, Hume and Hamilton, Whewell and Jevons, Greenleaf and Wharton, have failed to adapt their analyses of the principles of evidence to the needs of our time, their failure is due to the backwardness of physiology and pathology that must constitute the basis of the study of evidence, and on which the foundations for a reconstruction must be laid.

We do not yet know all of the human brain, either in health or disease; but our knowledge of it is sufficiently advanced to make it possible to see, with considerable clearness, its relation to testimony. If we do not know just how the cerebral cells evolve thought, we do know that thought is evolved by them or through them, and that various diseases of the brain and nervous system—now pretty well understood, but of which, twenty years ago, little or nothing was known—may utterly destroy the objective worth of thought, and render it, scientifically speaking, valueless.

The progress of cerebro-physiology and pathology, in recent times, has been mostly along the line of the Involuntary Life—a phrase which I have elsewhere and often used to designate those phenomena of mind or body, or of both, in their reciprocal relations, that are independent of will or consciousness, or of both. This Involuntary Life is the branch of physiology that has been least studied and least understood; its importance, however, is supreme, not only in itself, but on account of its relations to all other sciences. It is the one strategic point of modern thought, around which all the leaders in controversy are unconsciously gathering, and for the possession of which opposing hosts will soon contend. Here, as I have previously shown, is the last stand of modern delusions, of every name and form.[1]

The scientific study of human testimony requires a recognition of these three facts, in the physiology and pathology of the brain:

1. *The Limitations of the Human Brain in Health.*—Literature is so crowded with laudations of the human intellect, from the classic apostrophe of Hamlet—"What a piece of work is man! how noble in reason! how infinite in faculty! in form and moving, how express and admirable! in action, how like an angel! in apprehension, how like a god!"—down to the motto of Sir William Hamilton: "On earth there is nothing great but man; in man is nothing great but mind;" and so strong is the tendency in man to view himself from one side only, and to compare himself with the lower animals, or even with inorganic matter, that we are scarcely prepared for the conclusion to which a scientific study of the subject compels us, that, considered from all points of view—from what is above and beyond it, as well as from what is below and near it, from the aspirations that can never be realized, the vast but simple problems of the universe that it hopelessly strives to

[1] "The Scientific Basis of Delusions; or, a New Theory of Trance," etc., 1877.

solve, as well as from the narrow strip of territory it has subjected to science—the human brain is an organ of very limited capacity.

If some superior being endowed with superhuman, though not necessarily divine powers, should attempt to analyze the mind of man—to assign its relative position in creation, and to place it, properly ticketed and labeled, in some supra-terrestrial museum—it would be found to be a far less imposing object than man's own imagination has pictured it. If it be claimed, as it may be by some, that although this brain has thus far achieved but little, although, whether considered in the aggregate, the average capacity in many nations and through many generations, or, concretely in cases of individual and exceptional genius—as Socrates, Napoleon, Goethe, Newton, Shakespeare—it has fallen so far short of its desires and aims and apparent needs as not to merit the encomiums that poets and philosophers have lavished upon it, yet it has before it in this world, and in our present mode of being, a future of possibly infinite development, I may reply that the study of human testimony is in no way affected by such possibility, since it has to do only with the brain in the past, the present, or the near future.

The whole subject of the limitations of the human brain[1] is of high import, is very wide in extent, and suggestive practically as well scientifically and in ways almost innumerable, some of which I hope to point out at a future time; but, for the present purpose, the reconstruction of the principles of evidence, it is necessary to refer only to the following illustrations:

[1] The number of distinct thoughts of which the mind is capable in a given time is very limited, and can be estimated by experiment with considerable precision. Says Sir Henry Holland:

"Within a minute I have been able to coerce mind, so to speak, into more than a dozen acts or states of thought so incongruous that no natural association could possibly bring them into succession. In illustration I note here certain objects which, with a watch before me, I have just succeeded in compressing, distinctly and successively, within thirty seconds of time—the Pyramids of Gizeh, the ornithorhynchus, Julius Cæsar, the Ottawa Falls, the rings of Saturn, the Apollo Belvedere. This is an experiment I have often made on myself, and with the same general result. It would be hard to name or describe the operation of mind by which these successive objects have been thus suddenly evoked and dismissed. There is the volition to change; but how must we define that effort by which the mind, without any principle of selection or association, can grasp so rapidly a succession of images thus incongruous, drawn seemingly at random from past thought and memories? I call it an effort because it is felt as such, and cannot be long continued without fatigue.

"In commenting upon this a writer in *Nature* says: 'This is a curious subject which easily admits of experiment, but it will be found that the velocity with which thoughts can be made to succeed each other depends entirely upon the degree of similarity or connection between them. Judging from my own experience and that of three students well qualified to test the matter, I find that, where the objects thought of are as incongruous as possible, the number which the mind can suggest to itself in a minute varies from twelve, the result of Sir Henry Holland, up to about twenty. Any one who tries the experiment, however, will find that there is an almost insuperable temptation to go off on lines of association. To avoid these, and yet to think rapidly, requires a very disagreeable effort, becoming more and more painful by repetition. When the thoughts are restricted with-

1. The fact that success, even with the most richly-endowed natures, is only possible through specialism.

2. The imperfections and uncertainties of memory.

3. The exceedingly narrow limitations of the senses.

4. The fact that the best results of cerebral activity are largely involuntary, if not unconscious.

Specialism is not peculiar, as some would believe, to modern science or recent civilization; all the famous Greeks were specialists: one could not conceive of a Socrates, Homer, Phidias, Pericles, Demosthenes, and Sophocles, combined in a single individual. Although poetry and philosophy, being nearly allied, have been the twin products of one superlatively endowed intellect—although Goethe has demonstrated the possibility of uniting the genius of song with the genius of speculative science—yet no human being as yet proved himself at once great in poetry and mathematics. The combination of a Newton and Milton seems impossible; a conclusive and crushing deductive argument against the theory of the Baconian origin of Shakespeare's plays is, that no single brain could have produced the "Novum Organum" and "Hamlet."

In the present century, science has become so specialized that all the advances are made by specialists in comparatively restricted fields, by men whose entire energies are concentrated for a lifetime in some single path of research beyond which they never wander, and in which alone they are accepted as guides. So universal is this law of specialism that the instincts of men regard with suspicion any one who attempts to become an authority on more than one branch of science, while literature is so split up into divisions and subdivisions that eminence in all is unattainable. The lopping away of all superfluous branches, that bearing boughs may live, is carried to such an extreme that only one branch remains, and through this the whole cerebral force circulates. The human mind is like a stream which carries along the same amount of water, whether it flows through one channel or many. In spite of all the criticisms of specialism and specialists, the work of specialization has gone on, and in obedience to the law of evolution must yet go on; specialists are our sole authorities, even among those who despise them:

in certain grooves, as it were, the result is more rapid succession. Thus one student was able to think in a minute of thirty different kinds of actions, forty-six animals, fifty places or fifty persons. I can myself think, without much effort, of thirty-two animals or forty places or persons, in a minute. Even in these cases, however, it will be found that the rapidity greatly depends upon the degree in which the objects have been associated. When thoughts have been very closely and frequently linked together, the number of which may be compressed within a minute is much greater. I find that I can count about ninety-six in half a minute, which, without allowing for the two places of figures, gives one hundred and ninety-two thoughts per minute. I can think of every letter in the alphabet in five seconds at most, which is at the rate of more than three hundred per minute. Finally, by counting the first ten numbers over and over again, I have compressed nearly four hundred changes of idea within the minute.'"

science and specialism are identical; not to specialize is to lose the prizes of life. Germany, which in philosophy and science does the original thinking of the world, is, as we all know, a nation of specialists.

There are, it is true, degrees of specialism, and the term is largely a relative one: in medicine, where the word is mostly used, and where until recently it has been a term of more or less reproach, all general practitioners are really specialists, since medicine and surgery are both offshoots from the professions of the priest and the barber; in biology, some are authorities only on paleontology, others on natural history in general, others on some special branch, as entomology, others still on some one insect, as the bee; and this subdivision is continually going on with the evolution of systematized knowledge. These statements may be truisms to students of sociology, but they are truisms that are forgotten by all the writers on testimony, although, as we shall see, they lie at the root of the reconstruction of the principles of evidence.

Equally important in its bearings on the scientific study of testimony is the recognition of the fact that memory is far more untrustworthy than has been commonly supposed. But a very small fraction of the impressions made on the cerebrum are so far retained as ever to be called up at will. Theoretically, the brain is like a target on which every idea that is evolved makes a permanent impression which no subsequent impressions can thoroughly destroy; practically, it is rather like a series of sieves by which thoughts are sifted through various stages below and on the borders of consciousness and recollection, while only the coarser and larger grains are retained where they can be used when needed. Under the stress of special excitements—as in the terror of drowning or protracted falling, or in trance, impressions long forgotten are revived and rise to temporary consciousness, so that men suppose that the panorama of all their past lives is passing before them; but, even under such exceptional crises, it is certain that only a comparatively few of our mental impressions actually reappear; some long-forgotten events arise with vivid distinctness, and the startled subject believes that all his life is let loose.

Nearly all the acquisitions and experiences of life are forgotten, even by the best memories; only the tiniest trifle of past events or past knowledge can ever be recalled. How dreams are forgotten we all know, but the difference between the recollection of sleeping and waking thoughts is only one of degree; by the standard of memory, all life is a dream. The pleasant experiences of infancy and early childhood, which, if they could be recalled at will, would so enrich and glorify human existence, are to us as though they had never been; as maturity appears, childhood dies.

Children really, as compared with adults, have very poor memories; they forget almost everything; even in infancy the experiences of each year are wiped out by the experiences of the succeeding year; bright

babies pass through a succession of hobbies in their various games and sports, and methods of speech and conduct, likes and repulsions, and so forth, which are successively and almost completely forgotten. The whole process of education, public and private, is based throughout on the imperfections and uncertainties of memory. If it were possible for youths to retain what they read, or hear, or see, our schools and colleges might be closed, or, at least, remain open but one month in a year. With children, as with adults, life is but a series of unremenberable experiences; to live is to forget.

All boasted human learning is a temporary treasure, a loan rather than a permanent gift, which must be watched and tended every moment lest it slip from our possession. Truly has it been said that scholarship consists not in knowledge but in knowing where knowledge can be found: he is the learned man who knows not the contents of books but what the best books in any specialty are. School and academy and university graduates, who after years of active and it may be eminent professional life look over the examination-papers of *alma mater* and the catechisms of their childhood, find invariably that outside of the special lines of their lives they are unable to answer correctly and with certainty the simplest questions, and must conclude that all the wisdom of the world is with sophomores and school-children. Even special departments are, through the limitations of human capacity, so minutely specialized that one soon despairs of remembering anything more than what belongs to the daily routine in the pursuit of a specialty; an original author in science must continually refer to the books he has written, lest he forget his own discoveries.

Some experiments that I have made with the memory, the full details of which are to be published elsewhere, give results that are of the highest significance in their bearings on the study of human testimony. These experiments were modeled in part on the familiar "Russian game," so called, which is sometimes practised by the young as an amusement, and which consists in telling some short story to a party, who at once repeats it, or all that he remembers, or thinks he remembers, to another party, and so on through a series of half a dozen or more individuals. In order to make the experiment a fair one, and of value in the study of memory, the story designed as a test should be short and simple, and should be written out and clearly stated to the individual who stands second in the series. The second individual takes a third individual into another room, writes out the story from his recollection and reads it, the third party does the same by the fourth, and so on. When all the stories are compared, at the close of the experiment, this general result is invariably reached:

1. No two of the stories agree. All have departed more or less widely not only from the original, but from the account which they themselves directly received from the person next to them in the series.

No one has succeeded in remembering just what his neighbor told him, although he wrote down instantly what he heard.

2. In some of the stories interpolations occur, as well as omissions. These additions are sometimes of an important nature, seriously modifying the thought of the original, and, what is more strange is, that these are frequently believed by the authors to be parts of the original; they are sure that they have given only what was given to them, and are astonished and incredulous when a comparison is made between the original and the others in the series. Not only the phraseology but the thought is changed.

Another method of experimenting with the memory is, to repeat the same story to a number of individuals separately, and then, after all have written out by themselves without conference what they can remember, to compare the results.

Experiments of this kind, it will be observed, are made under every conceivable advantage: there is no haste; there is no excitement, at least after the novelty is over; there are no distractions; the power of recollection of words and facts is at its best. The accounts are written down instantly as they are received; they are consequently the virgin impressions on the brain. I have made these experiments with intelligent, liberally-educated persons of both sexes, and have repeated them sufficiently often to demonstrate that the results noted here are laws and not exceptions; and it is as clear as any fact in science can be, that works like Boswell's "Life of Johnson," and Goethe's conversations with Eckermann, and Luther's "Table-Talk," and indeed all conversational literature, must be regarded as representing the tendencies of the heroes of the conversations, the general drift of their uttered thought, rather than the precise language employed, or the order in which the statements were made. Certain phrases often repeated by an eminent man in the presence of his friend may be in some instances literally transcribed, especially if they are of an original and striking character; but exact details of long conversations are never recalled—except perhaps by certain prodigies of whom I shall presently speak. Interviewing reporters are sometimes unjustly censured for intentionally interpolating errors in their published statements. The day following an interview, or even five minutes after, neither party can tell precisely what has been said, although sufficient may be remembered for practical needs. Conversation can only be accurately reported when it is taken down at once as the words are uttered. Conversations reported weeks, months, and years, after their occurrence, must be not only wide, but very wide, of the facts; and, besides the positive omissions, there must be, in all cases, interpolations or additions both of fact and of language which the author is confident, and very likely has all along been confident, that he received from the original. The subjective is confounded with the objective, and there is no way by which they can be distinguished.

These experiments bear directly and obviously on history and on legal testimony, they show the hollowness of much of what is called historic evidence, and the uselessness of the attempt so often made in court to force or coax witnesses to give the exact language used by them, or to them, or in their presence. I once told a short story to a person who has the most remarkable memory both for words and facts of any one whom I have ever met, and requested him to at once repeat it. He attempted to do so, and not only changed the phraseology, but left out one of the most important details. In some cases I have requested the subjects experimented on to wait a week or ten days, and then to write out what they remember, or think they remember, of what was told them. In all cases there will be variations from the original of greater or less importance, according to the nature and complications of the story, and the special memory of the individual. One person, a scholar of unusual verbal memory, after carefully studying a short story, consisting of less than one hundred words, and waiting ten days, made eight blunders.

In elaborately comparing the recitations of experienced and eminent actors and actresses with the originals of plays, I find that serious verbal changes, both of omission and interpolation, are constantly made. Dramatic teachers say that pupils cannot accurately retain a long part; that blundering is everywhere the rule. Shakespeare, in his choicest passages, is almost always, unintentionally if not unconsciously, altered even by his most skilled and practised interpreters.

The statement made by Renan in his latest work, on "The Origins of Christianity," that persons who do not know how to read and write have a better memory for oral communications, is not confirmed by my experiments thus far; scholars and thinkers remember words and ideas better than the ignorant and unreading classes. Those who do not know how to read and write find it hard, according to my experiments, to retain in memory a short and simple sentence, even for an instant. Not only memory of words, but of facts and objects of common observation, is more limited than is supposed.

In another series of experiments I tested the power of recalling the objects that fell upon the vision. If a number of persons enter a room containing a number of articles of furniture, with various colors on the walls and in the carpet, and in which certain complex gestures or motions or manœuvres are made by some one, there will be no agreement in their reports, even if made at once, and no report will be accurate.

For years philosophers and critics have been asking how long time is required to make a myth. The answer is found in these experiments. A myth can be made in a minute. These interpolations and additions to reported conversations, of the truth of which the reporter, at the time and subsequently, is so fully persuaded, that only by a comparison with the written original can he be undeceived, are the products of the reporter's own mind—the unconscious substitution of the subjective for the

objective words and phrases and thoughts of his own brain, which, perhaps, have long been parts of his mental possessions, rise up like ghosts in the midst of his narration, throw aside the original words and phrases and thoughts, and take their places so perfectly and so harmoniously that the intrusion is not suspected.

It may be said—indeed, it is often said—that memory is a distinct and narrow faculty, in no way correlated to other and more important faculties, and that its perfectness or imperfectness has little relation to the cerebral force. Even if this view of the nature of memory were the correct one, it would not invalidate what is here claimed of the relation of memory to human testimony. But this theory of the nature and office of memory is not the correct one; it is opposed to all that is known of the brain and of its functions, whether studied physiologically or psychologically. Memory is simply a register of a small fraction of the impressions made on the brain; there are, therefore, as many different kinds of memory as there are different faculties or combinations of faculties. Memory is a measure of mind; but, as there are as many varieties of memory as there are varieties of talents in man, the memory of any man can only measure the talent peculiar to himself. We remember what we have a capacity to comprehend. Any man, it has been said, is willing to admit that his memory is poor, but no one will admit that his judgment is poor; and yet judgment is largely the result of memory. One may have a good judgment in some departments, but a very poor judgment in other departments; but, in those departments in which the judgment is good, the memory must also be good.

The relation of memory to mind is illustrated, if not demonstrated, in the early and late history of infant prodigies, such as blind Tom the musician, Colburn the mathematician, and the famous "boy orator." An analysis of the mental powers of any of these prodigies brings out these four facts common to them all: 1. Extraordinary memory in some one department; 2. Correspondingly extraordinary genius in that department; 3. Marked and unusual deficiency of other mental qualities, amounting in some instances to idiocy; 4. Decline of their special gifts corresponding to the development of other faculties on reaching maturity. "In monstrosities Nature reveals her secrets;" the physiology of mind, the general relation of mind to brain, and the relation of memory to mind, can all be studied effectively through infant prodigies. In no class of beings are the limitations of the human brain so thoroughly demonstrated as in these very prodigies that are supposed to illustrate in a marvelous way the capacities of intellect: all their special endowments are bestowed at the price of general endowments; the ordinary is sacrificed to the extraordinary. If they ever mature and become well-balanced citizens, the particular genius that made their childhood famous must correspondingly suffer. Even the average child, as we have seen, loses its memory in certain directions as it advances to maturity; hence the common but erroneous belief

that the memory of children is better than the memory of adults. In truth, average children remember far less in quantity than adults, and they remember different things according to their age and taste. With children as with adults, and as with prodigies, the memory, scientifically studied, is an exact measure of mind, and in all, old and young, its limitations are so great as to impair most seriously the value of most of human testimony, even in matters of every-day life; while in all science, or the capacity of the human brain for observing systematized knowledge, for thinking and for remembering, is so limited that the world must defend, and practically, in the face of all the teachings of logicians and authorities on evidence, does defend, and rests its faith exclusively on, the testimony of experts, and in claims of new discoveries, especially against antecedent probability, on the testimony of a few only, and those of the very highest character—experts of experts—the opposing testimony of millions and millions of non-experts, though concurring and including the best and wisest of mankind, through all the ages being justly regarded as worse than worthless.

THE GROWTH OF THE STEAM-ENGINE.[1]

By Professor R. H. THURSTON,
of the Stevens Institute of Technology.

VI.

THE STEAM-ENGINE OF THE FUTURE, AND ITS BUILDER.

HAVING thus rapidly outlined the history of the steam-engine, and of some of its most important applications, we may now take up the question—

What is the problem, stated precisely and in its most general form, that engineers have been attempting here to solve?

After stating the problem, we will examine the record with a view to determine what direction the path of improvement has taken hitherto; and, so far as we may judge the future by the past, by inference, to ascertain what appears likely to be its course in the present and in the immediate future. Still further, we will inquire what are the conditions, physical and intellectual, which best aid our progress in perfecting the steam-engine.

This important problem may be stated in its most general form thus:

To construct a machine which shall, in the most perfect manner possible, convert the kinetic energy of heat-motion, as derived from

[1] An abstract of "A History of the Growth of the Steam-Engine," to be published by D. Appleton & Co.

the combustion of fuel, into mechanical power, using steam as the receiver and conveyer of that heat.

The problem embodies two distinct and equally important inquiries: The first, *What are the scientific principles involved in the problem, as stated?* The second, *How shall we construct a machine that shall most efficiently embody and accord with not only known scientific principles, but also with all well-settled principles of engineering practice?*

The one question is addressed to the man of science; the other to the engineer. They can only be satisfactorily answered, even so far as our knowledge at present permits, after studying with care the scientific principles involved in the theory of the steam-engine, under the best light that science can afford us, and by a careful study of the various steps of improvement that have already taken place, and of accompanying variations of structure, analyzing the effect of each change and tracing the reasons therefor. The theory of the steam-engine is too important and too extensive a subject to be treated in even the space available for a complete course of college lectures; and we can only here attempt an exceedingly concise statement of the principles, pointed out by science, as those applicable in the endeavor to increase the economic efficiency of the steam-engine.

The teachings of science indicate that, in the modern steam-engine: *Success in economically deriving mechanical power from the energy of heat-motion will be the greater as we work between more widely-separated limits of temperature, and as we more perfectly provide against losses by dissipation of heat in directions in which it is unavailable for the production of power.*

Scientific research has proved that, in all varieties of heat-engines, a very great loss of effect is unavoidable from the fact that we cannot reduce the lower limit of temperature, in working, below a point that is far above the absolute zero of temperature: the point corresponding to the mean temperature of the surface of the earth in our latitude is now practically our lower mean limit of temperature. The higher the temperature of the steam, however, when it enters the engine, and the lower the temperature at which it leaves the cylinder, and the more thoroughly we provide against waste of heat by conduction and radiation, and of power by friction, the greater will be our success.

Now, looking back over the history of the steam-engine, we may rapidly note the prominent points of improvement and the most striking changes of form; and we may thus obtain some idea of the general direction in which we are to look for further advance.

Beginning with the machine of De Caus, at which point we may first take up an unbroken thread, it will be remembered that we there found a single vessel performing the functions of all the parts of a modern pumping-engine; it was at once boiler, steam-cylinder, and condenser, as well as both a lifting and a forcing pump.

The Marquis of Worcester, and, still earlier, Da Porta, divided the

engine into two parts; using one part as a steam-boiler, and the other as a separate water-vessel.

Savery duplicated those parts of the earlier engine which acted the several parts of pump, steam-cylinder, and condenser, and added the use of the jet of water to effect rapid condensation.

Newcomen and Cawley next introduced the modern type of engine, and separated the pump from the steam-engine proper: in their engine, as in Savery's, we notice the use of surface-condensation first; and, subsequently, that of a jet of water thrown into the midst of the steam to be condensed.

Watt finally effected the crowning improvement of the single cylinder-engine, and completed this movement of differentiation by separating the condenser from the steam-cylinder, thus perfecting the general structure of the engine.

Here this movement ceased, the several important processes of the steam-engine now being conducted each in a separate vessel. The boiler furnished the steam; the cylinder derived from it mechanical power; the vapor was finally condensed in a separate vessel; while the power, which had been obtained from it in the steam-cylinder, was transmitted through still other parts to the pumps, or wherever work was to be done.

Watt also took the initiative in another direction: He continually increased the efficiency of the machine by improving the proportions of its parts and the character of its workmanship; and thus made it possible to render available many of those improvements in detail which are only useful when the parts can be skillfully made.

Watt and his contemporaries also commenced that movement toward higher pressures of steam, used with greater expansion, which has been the most striking feature noticed in the progress of the steam-engine since his time. Newcomen used steam of barely more than atmospheric pressure, and raised 105,000 pounds of water one foot high, with a pound of coal consumed. Smeaton raised the steam-pressure to eight pounds, and increased the duty to 120,000. Watt started with a duty of double that of Newcomen, and raised it 320,000 foot-pounds per pound of coal, with steam at ten pounds. To-day, Cornish engines of the same general plan as those of Watt, but worked with forty to sixty pounds of steam, and expanding three to six times, do a duty that will probably average, with good ordinary engines, 600,000 foot-pounds per pound of coal.

The increase of steam-pressure and expansion which has been seen since Watt's time has been accompanied by a very great improvement in workmanship, a consequence of rapid increase in the perfection and the wide range of adaptation of machine-tools, of higher skill and intelligence in designing engines and boilers, increased piston-speed, greater care in obtaining dry steam, and in keeping it dry until thrown out of the cylinder—either by superheating, or by steam-jacketing, or

by both means combined; and it has been further accompanied by greater attention to the important matter of providing carefully against losses by conduction and radiation, and by internal wasteful transfer of heat. The use, finally, of the "compound" or double-cylinder engine for the purpose of reducing friction, as well as of saving some of that heat which is usually lost in consequence of internal condensation and reëvaporation due to great expansion, has already been considered when treating of the marine engine.

It is evident that, although there is a limit, which is tolerably well defined, in the scale of temperature, below which we cannot expect to pass, using the now standard type of engine, a degree gained in approaching this lower limit is more remunerative than a degree gained in the range of available temperature, by increasing the maximum temperature. Hence, the attempt made by the French inventor, Du Trembly, a quarter of a century ago, and by other inventors since, to utilize a larger proportion of heat by approaching more closely the *lower* limit, was in accordance with what are now well-known scientific principles.

The form of engine here referred to is known among engineers as the Binary Vapor-Engine. In it the heat usually carried away by the water delivered from the condenser of the steam-engine is made to evaporate some very volatile liquid, as ether or carbon bisulphide, which, in turn, by the expansion of its vapor, develops additional mechanical power. Mechanical difficulties have hitherto prevented the success of this form of engine; but it cannot be pronounced impossible that coming inventors may make the system commercially valuable.

An important consequence of the still unchecked rise of piston-speed in the modern steam-engine is the approach to a limit beyond which the now standard form of "drop cut-off," or "detachable" valve-gear, cannot be used. For the piston would, at that limit of speed, reach the end of its stroke before the dropped valve could reach its seat, and the point of cut-off and degree of expansion could no longer be determined accurately and invariably by the governor. This limit has probably already been attained in some engines; and the engineer adopting such piston-speeds as 1,000 feet per minute or more is driven back to the use of the older types of "positive-motion" valve-gearing, and is compelled to devise special forms of governor which shall have sensitiveness, and yet power sufficient to control these less tractable kinds of mechanism, and to invent reliable and durable forms of balanced valves, and to practise every practicable expedient for making the movement of the valve, and its adjustment by the regulator, perfectly easy. Positive motion and ease of adjustment by the governor are, therefore, evidently the requisites of a successful valve-gear for the engine which will probably succeed the standard engine of to-day.

We may now summarize the results of our examination of the growth of the steam-engine thus:

1. The process of improvement has been one, primarily, of "dif-

ferentiation;" the number of parts has been continually increased, while the work of each part has been simplified, a separate organ being appropriated to each process in the cycle of operations.

2. A kind of secondary process of "differentiation" has, to some extent, followed the completion of the primary one, in which secondary process one operation is conducted partly in one and partly in another part of the machine. This is illustrated by the two cylinders of the compound engine, and by the duplication noticed in the binary vapor-engine.

3. The direction of improvement has been marked by a continual increase of steam-pressure, greater expansion, special provision for obtaining dry steam, higher piston-speed, careful protection against loss of heat by conduction or radiation, and, in marine engines, by surface condensation.

The direction of improvement, as indicated by science as well as by our own review of the actual steps already taken, would seem to be: *En résumé*, working between the widest attainable limits of temperature, and the saving of heat previously wasted in the apparatus or rejected from it.

Steam must enter the machine at the highest possible temperature, must be protected from waste or loss of heat, and must retain, at the moment before exhaust, the least possible proportion of originally available heat. He whose inventive genius, or mechanical skill, contributes to effect either of these objects—to secure either the use of higher steam with safety, or the more effective conversion of heat into mechanical power without waste, or the reduction, by transformation into work, of the temperature of the rejected working-fluid—confers an inestimable boon upon mankind.

In detail, in the engine proper the tendency is, and may be expected to continue, in the near future at least, toward higher steam, greater expansion in more than one cylinder, steam-jacketing, superheating, a careful use of non-conducting protectors against waste, and higher piston-speed with rapid rotation, and to the adoption of special proportions and of forms of valve-gear adapted to such high-speed engines.

In the boiler, more complete combustion, without excess of air passing through the furnace, is sought, and a more thorough absorption of heat from the furnace-gases. The latter may be ultimately found most satisfactorily attainable by the use of a mechanically-produced draught, in place of the far more wasteful method of obtaining it by the expenditure of heat in the chimney.

In construction, we may anticipate the use of better materials, as already seen in the substitution of "mild steels" for the cruder material, iron, and more careful workmanship, especially in the boiler, and still further improvement in forms and proportions of details.

In management, there is an immense field for improvement, which

improvement we may feel assured will rapidly take place, as it is now becoming well understood that care, skill, and intelligence, are absolutely essential to economical management, as well as to safety, and that they repay liberally all the expenditure of time and money that is requisite to secure them. It is truer of labor than of anything else in the market that "the best is the cheapest."

In attempting improvement in the directions that I have indicated, it would be the height of folly to assume that we have reached a limit in any one of them, or that we have even approached an impassable limit. If further progress seems checked by inadequate returns, when efforts are made to advance, in any promising direction, beyond present practice, it becomes the duty of the engineer to detect the cause of such hinderance, and, having found it, to find a way to remove it, if such removal is not physically impossible.

A few years since the movement toward the expansive working of high steam was checked by experiments seeming to prove positive disadvantage to follow advance beyond a certain point. A careful revision of results, however, showed that this was true only with engines built, as was then common, in utter disregard of all the principles which should have been observed in such use of steam, and of the precautions necessary to be taken to insure the gain which science has taught us should follow the intelligent use of higher pressures of steam. The obstructions are purely physical and mechanical, and it is for the engineer to remove them.

An analysis of the methods of waste of heat, in the operation of the modern steam-engine, would show that a very large proportion—nearly all, in fact—is due to the rejection of unutilized heat with the exhaust-steam. In the best engines in general use this loss amounts to from eight-tenths to nine-tenths of the total amount of heat derived from the fuel. Modern steam-engines lose nearly all wasted heat in this way; the losses by conduction and radiation are comparatively small. It is at once evident that the only way in which any very great additional economy can be secured is to reduce to a minimum the quantity of heat remaining at the opening of the exhaust-valve, and then to retain this rejected heat within the system, so far as is possible, and to thus prevent its waste by escape from the system. The reduction of the great quantity of heat left for rejection at the end of the stroke of the piston can only be effected, to any important degree, by expedients which check that internal condensation and reëvaporation which, with great expansion, transfer to the condenser, unutilized, an immense amount, often, of the heat supplied. As already stated, these expedients are the use of dry steam, the adoption of the steam-jacket and of high engine-speed, and the use of a material for the interior lining of the cylinder which has the least possible conductivity.

The retention of the heat actually rejected from the cylinder, and its complete utilization by reworking, is practically a matter of diffi-

culty, although not certainly impossible;[1] and the author has proposed a new type of steam-engine, in which the water of condensation and the steam rejected from the engine shall be separated and returned, by pumps of proper proportion and construction, to the boiler. The return of the water demands the expenditure of an insignificant amount of power. To return the rejected steam with its charge of heat—which usually forms so large a proportion of the total heat generated by the combustion of the fuel, assuming all transfer of heat to the exhaust by the operation of internal condensation and reëvaporation to have been prevented—demands the expenditure of precisely the amount of power which has been developed by its expansion. In an ideal engine of this type, therefore, the efficiency is perfect, and all heat-energy is utilized by transformation into mechanical energy; but the engine cannot develop as much power as an engine of the common type of the same size. The size of engine will be nearly inversely proportional to the "efficiency of the fluid" under similar conditions in this and the ordinary type of engines. The heat rejected from the cylinder has been degraded so low on the scale of temperature as to be no longer available for the production of power; nevertheless, restored to the boiler, it serves with perfect efficiency as a basis upon which to "pile up a new stock of utilizable energy" in the form of heat derived from the furnace, and at a higher temperature.

The obstacles to the realization of this theoretically perfect type of engine are those which make it so difficult to reduce internal condensation and reëvaporation, and those conditions of practice which make the engine of this type exceptionally bulky and mechanically inefficient.

Whether this type of heat-engine can ever be made of practical value will be determined by the rate of condensation of steam expanding against a resisting piston; the extent to which high pressures and great expansion can be practically carried; the extent to which internal transfer of heat, without doing work, can be reduced; the practical limit of engine-speed; and the perfection attainable in the engine considered as a piece of mechanism. All these conditions remain to be experimentally determined, and it is only by their determination that it can be known whether the "Steam-Engine of the Future" will greatly exceed the engine of to-day in efficiency, and whether this newly-proposed type may ultimately succeed.

That the changes in practice already indicated may go on almost indefinitely seems unquestionable. That this latter modification of the steam-engine will ever actually take place, and become generally adopted, cannot be as positively asserted. We may, at least, hope that it may.

We have seen that the most important problem offered the engineer

[1] "On a New Type of Steam-Engine," etc., by R. H. Thurston, *Journal of the Franklin Institute*, October, November, December, 1877. "Proceedings of the American Association for the Advancement of Science," 1877.

for solution is a double one, and that it requires the aid of both the scientist and the mechanist in its solution.

But it is sufficiently evident that, before the engineer can determine what form of machine will best yield to him full control of these forces of Nature, he must have sufficient knowledge of science to be able to understand what scientific principles are to be rendered available, and what phenomena of Nature are operating in the production of the power which he is to seize upon and usefully to apply. Otherwise, he will grope in the dark, and will only learn, by the bitter experience of costly failures, to make slow progress toward perfection.

We have seen that the larger proportion of the principal improvements which have yet been effected in the steam-engine were due to the united engineering skill and experience and scientific attainments of James Watt. We have seen that his improvements followed a long course of intelligent and truly scientific research; and that, directed by the results of this investigation, the engineering talent and the mechanical knowledge of the great inventor accomplished more in a single lifetime than had been previously accomplished in the whole period embraced in the history of civilization.

This great example confirms what we should infer from the nature of the problem itself, that—

He who would accomplish most in the profession of the mechanical engineer must best combine scientific attainments—and especially experimental knowledge—with mechanical taste and ability and a good judgment refined by engineering experience.

As one of our oldest engineers[1] tells him, he must "cultivate a knowledge of physical laws, without which eminence in the profession can never be securely attained." He must become familiar not only with science and the arts, but he must train himself to make the one assist the other; he must learn just how to make use of scientific principles in planning his work, and how to do his work most thoroughly, efficiently, and economically, when he has determined his general design. He must be able to determine how far standard designs are in accordance with correct scientific and mechanical principles, to detect their defects and the causes of those defects, and to provide a remedy correct in principle and mechanically efficient. Science and Art must always work hand-in-hand.

But how are the rising generation of engineers to acquire this proficiency in both branches of knowledge? How are they to be made mentally and manually accomplished; how fitted for the great work which is laid out for them?

The time has gone by when, in any art, the ignorant and merely dexterous workman can compete with even a less skillful shopmate, who possesses and uses brains as well as hands, and knows how to make the the one direct and aid the other. We to-day find him occupying a

[1] Charles Haswell.

decided vantage-ground who is at the same time familiar with the schools and at home in the workshop. For whatever department in the arts a youth may be designed, he must, to insure success in the future, be taught not "*in either the school or the workshop*," the alternative formerly offered him, but in the school *and* the workshop.

Here, then, arises the necessity for TECHNICAL AND TRADE SCHOOLS, in which, if properly conducted, knowledge is imparted so as not only to train the mind to habits of thought and study, to give it capacity for logical deduction and the rapid acquirement of information, but in such manner as shall at the same time make the student familiar with the principles of the art which he is to practise, and shall prepare him to learn the lessons taught, in the workshop and in the manufactory, rapidly and well.

It is the tardy recognition of these facts, of this vital necessity, that has placed a great nation, formerly far in advance of all others in manufactures and the useful arts, in a position relatively to her neighbors that is causing the greatest uneasiness to the more intelligent of her people and to all her statesmen. They see other nations, who were formerly far behind, now rapidly overtaking her, if not already taking the lead, in consequence of their earlier adoption of a system of technical instruction for their people.

Two hundred years ago, Edward Somerset, the second Marquis of Worcester, the inventor, whose work has become familiar to us, admonished his fellow-countrymen of the growing necessity of such a system of education for the people, and urged the establishment of technical schools. For this he deserves higher honor than for his improvements in the steam-engine. But the system first took a definite shape, a century ago, upon the Continent of Europe; and, during the past half-century, it has grown with the growth and strengthened with the strength of the western European nations, until, to-day, it has become a most important element of their national power.

In our own country, this great need has long been recognized; but the policy of our Government has not permitted it to institute systems of teaching at the expense of the nation, as has been done in European countries, and it has remained to a great degree unprovided for. It is to our sad deficiency in this respect, and to the tardy and unconcerted action of our educators and our legislators—few of whom seem to have the calibre of the real statesman—that we are to-day so seriously behind Continental nations in the industrial education of youth, and are threatened with serious evils in the future. Without general and systematic technical and trade education, the most enterprising people on the globe, brought into competition in the markets of the world with better-educated people and with nations of trained artisans, must inevitably become a great nation of paupers.

Such education cannot be provided at the small cost that the working-man can afford to pay; and, even if that were possible, it is doubt-

ful whether the vital necessity of such education, to the people rather than to the individual, and to the coming rather than to the present generation, would be sufficiently well understood by the average citizen to induce the payment of its actual cost, far below its full value as it may be.

It becomes, therefore, the privilege and the duty of the wealthy among our citizens to provide this great want of our country, and to aid thus most effectively in giving her that preëminence among nations that every patriotic citizen desires her to attain.

THE STEVENS INSTITUTE OF TECHNOLOGY.

THE RELATION OF THE FINITE TO THE INFINITE.

BY N. J. GATES.

ALL human knowledge is limited—limited by the power of the senses, limited by the scope of the senses, limited by the imperfections of the senses. The eye cannot see an atom, because of its minuteness; it cannot measure the sun or the stars, because of their vastness; it can only be trusted to take the approximate and comparative measure of a limited class of objects within certain distances.

This conscious narrowness is realized in all the special senses and all the faculties of the intellect.

We have pains so slight that we never feel them, yet in their aggregate effect they may be fatal; and a fatal blow that shall at once strike down every nerve of sensation would produce as little conscious pain. Consciousness cannot mark its own beginnings or endings; it can only realize intermediate stages. We have no consciousness of how or when we *began* to see, or feel, or think, and we will probably have as little as to their mode of termination. As conscious physical beings (we are not discussing the question of immortality), the cradle

and the grave meet in one mystery. It is the putting *on* and the putting *off* of consciousness; all that lies between we call life—finite, limited life.

Now, it seems plain that a mind so restricted by the senses can never form a just conception of the infinite. How utterly impossible it is for us to grasp the idea of endless space or endless time! To suppose there is an end to space is to suppose something *beyond*, and this must be space. To suppose there was a moment when time began is to suppose there was a moment *before* it began, and this must have been time also. Let us conceive God to be the highest possible ideal of the Infinite; let us assume that he had no beginning, and that he fills with his presence all space. But we cannot conceive of a universal, all-pervading God without all-pervading space; and, consequently, if God had no beginning, neither had space, and if space had no beginning, neither had time. Then, as a sequence, God did not *create* time or space, for they were prerequisites to his own existence. Hence our highest conceptions of God *condition* him of necessity.

Now, it may be asked, "Does this line of reasoning prove there is no God?" Not at all. It simply proves that the *finite* mind is utterly impotent to apprehend God. It proves that we do not and cannot comprehend primary causation; that our perceptive faculties are so limited by the very nature of their constitution that they cannot apprehend the primary nature of the simplest natural law; and if we cannot comprehend the nature of the *force* called gravity, or heat as a mode of motion, except as physical *facts*, how can we have any rational conception of any of those matchless qualities of mind that produced these laws? If the rude savage, after examining for the first time a complicated piece of machinery, can form no just conception of the forces that impel it, or even of the purpose it serves, how much less can he understand the peculiar qualities of mind that invented and produced it! If, by dint of deepest research, we cannot analyze the subtile law that connects the molecular movement of the brain with thought, how can we analyze the thoughts of an Infinite mind of which this law was but a thought? Is it not plain that, in attempting this, we attempt the impossible?

Let us give a simple illustration to show how utterly incompetent is the finite mind to grasp the idea of creation—we mean *absolute* creation. It must be conceded that matter has either had an eternal existence (whatever that may mean), or it has been called into being—created by a Creator. But it may not have occurred to every one that to the finite rational mind the latter idea is as incomprehensible as the former, for we cannot conceive of the creation of *something* out of *nothing*. "From nothing, nothing can come." The science of geometry is based upon axioms not more self-evident. So far as the finite mind can reason, it is as impossible for God to create something

from nothing as it is for us to prove that a whole is not greater than any of its parts, for it is a self-contradiction. The reader will bear in mind that we are not discussing the *facts* of the creation, but the incompetency of the human mind to grasp the facts, whatever they may be. However humiliating, then, it may be to the pride of human intellect, we are forced to the conclusion that there is a vast field of thought, open to anxious inquiry it is true, over the gateway of whose entrance we may well inscribe, "THE UNKNOWABLE." Somewhere within this vast field, from which the human intellect is excluded, lie absolute time and space, and all we call creation, or primary causation. It is the futile attempt to explore this field that has brought philosophers and theologians alike into deserved contempt—the old folly of perpetual motion by the construction of a clock that shall wind up itself.

It is now time for science to define, in some way, the limitations of human knowledge, and thus confine all research strictly within the sphere of the knowable. Is it not safe to assume that the finite mind is so conditioned that it cannot possibly perceive or comprehend ultimate antecedent causes? To say that God was the first cause seems at first an easy solution, but it is only another way of saying we do not know, for we ask at once, "Had God a beginning? and if not, then for an infinite period of time he was *alone*, or else matter has been coeternal with him, and we come back to the Hindoo idea that God is the universe. Our conception of God must be the essence of our conception of eternity, and of that the finite mind can of necessity form no conception. There is a mathematical ratio between a second of time and a million million centuries; but there can be no ratio between a million million centuries and eternity, hence our conception of an infinite and eternal God is impossible. The difficulty does not lie so much in the vastness of the idea itself as in the seeming impossibilities the idea involves. It is like attempting to show the necessity for a sixth sense, by expressing this want or necessity in terms of the five senses we already possess; no such idea can by any possibility be conveyed.

Let us compare an animal as low in the scale of existence as an oyster with one of the highest known type, man, and note the points of agreement and the points of divergence. An oyster, like man, is evolved from a germ, advances to the climax of animal vigor, and then, like him, declines and dies. An oyster's life is conditioned by the elements in which he lives, and so is man's. An oyster, like man, is propagated by well-defined laws, and like him is subject to disease and premature decay. Now, in all the conditions named, there is not only no difference in kind, but, so far as we know, there is none in quality. They are conditions expressed in universal laws to which the entire organic kingdom is subjected, and over which human agency has little or no control. Let us now turn to those higher qualities in man which are

either entirely wanting in the oyster, or are of the most rudimentary nature.

The nervous structure of an oyster is so low that we can no more detect consciousness than we can detect the physical structure of an atom. In man the nervous organization is exceedingly complicated, and centres in a massive brain unparalleled in its activity; to this are added the special senses (probably entirely wanting in the oyster), through which alone all knowledge comes to the mind. Now, we observe that all the inflexible laws that, in the same way, limit and govern these extremes of organic life, are of the infinite order, having their beginnings beyond the scope of the senses, while the differences are of the finite order and grow out of the relation of one thing to another; in other words, the difference is one of degree, and therefore finite. There was a time, in the infantile development of every man, when he was as unconscious of all his higher functions as the passive oyster; but there came a time when, through the special senses, he began to take on thought, which is an impression made upon the brain by external action, and these impressions multiply and accumulate as we come more and more in contact with surrounding objects, until the accumulated thoughts are called knowledge; that is to say, the mind is evolved from *without*, and not from *within*. It is utterly impossible for us to conceive of anything bearing no likeness to anything we have ever seen, or heard, or felt, because our thoughts are the result of impressions already made. We certainly can form no conception of a color unlike any of the prismatic colors and their combinations, because, through the organ of vision, no other impressions have been made upon the brain.

The difference in the scope of the receptive and perceptive faculties of the lower order of organisms, as compared with those of the higher, is vast and almost incomprehensible, just as is the difference in distance between two contiguous atoms and two of the most widely-separated visible stars, but it is a difference of degree and is finite. The great underlying life-principles are the same in each, and for want of a better name we call them principles of the infinite order.

Now, we insist that a well-defined line may be drawn between simple forces of the infinite order and a *result* growing out of the changed relation of one force to another—a difference between simple and resultant forces—the one constant and unvarying, the other forever changing. We may fashion metallic wheels and put them into certain relations to each other, and by employing weights or springs construct a clock that shall mark time in minutes or seconds, and by changing the relation of parts we may measure weeks or months, omitting to note the subdivisions, varying these results at pleasure; but in all this we *create* nothing, nor do we in any way modify a pre-existing principle. The mathematical laws of multiples, by which the results of all the wheel-movements are determined, *preëxisted* in the infinite and indestructible laws of numbers and of motion, and the

direct motive power preëxisted in the force of gravity, or in the elastic property of the molecular structure of the spring. In bringing the wheels together, and making all the adjustments, we create neither force nor quality—in separating them and breaking the connections, we destroy nothing. The same is true of all mechanism, and indeed of all organisms. Chemical atoms are endowed with definite, inflexible, and indestructible properties that produce different effects only when differently related or correlated.

The difference between organic and inorganic conditions of existence is not a difference in the powers or properties of matter traceable to first causes, but to changed relations due to secondary causes; just as the movement of pieces upon the chess-board does not change the number or the power of the pieces, but, from their changed relations to each other, arise new and highly-complicated effects, that are perhaps never repeated in playing a million games. It is for this reason that no two organisms are ever exact duplicates of each other, nor is the individual ever twice in the same physical or intellectual conditions.

Now, is it not plain that, in the investigation of all the simple forces of which we have the slightest knowledge, there is not one in which we can find a comprehensible beginning? We trace them one by one from highly-involved conditions, through the less and less involved, until at last the simple force, divorced from all associated relations, is lost in the azure blue of the *infinite—infinite* in the space it may occupy—*infinite* in its duration—*infinite* in the diversity of effects that may arise from association with other simple forces, and *finite* or *comprehensible* alone in the *duration* of these conditions. It is at just this point we desire to draw the line between the knowable and the unknowable. All attempts to find the relation existing between *first cause* and any sequence or effect must utterly fail, for, as we have already seen, it is an effort of the mind to comprehend infinite conditions—to produce something from nothing. To say that God, in his creative energy, was the first cause, is to say that all the conditions of creation *preëxisted in him*, and, if all the conditions and possibilities of creation preëxisted in God, *creation itself* preëxisted in him, and consequently had no *beginning*, for the conditions by which creation was alone made possible, and which were its foundation-stones, were certainly *first causes*, and, if God created them, he created himself, which is absurd.

When we grant that the material universe contains in itself no creative energy, and that all the manifold laws by which seemingly blind atoms rise by intelligent coördination to organic conditions, and thus to intellectual activities, have not created themselves, we have exhausted the argument for materialism as a possible explanation of First Cause. And now we appeal to an Infinite Intelligence, a spiritual essence, superior to material conditions, and attempt to satisfy reason by making the universe the sequence of a Sovereign Will? But have

we advanced a single step toward the comprehension of First Cause? We say, no! but on the contrary are receding from it; for we assume that the vast continuity of effects which we call the universe, past and present, must have had an antecedent cause, and this First Cause, which certainly must be more potent than the universe it created, we assume existed and preëxisted without cause. That is to say, we rise from the smallest phenomenon in Nature by slow gradations, connecting cause with effect, until we reach the highest phenomenon above Nature, and this we assume came into existence without cause, or in other words the source of all other powers is itself an underived power, and either created itself or was never created, either of which is unthinkable. It is, indeed, the conception of a vast and stately intellectual pyramid resting upon a vast base, which it is assumed requires no support.

Let no devout critic challenge the physicist to explain primary causation until he can show the capacity of the finite mind for the reception of such an idea, nor on the other hand deceive himself with the idea that he has removed the difficulty by simply covering it with a name, the meaning of which is utterly incomprehensible.

LIQUEFACTION OF THE GASES.[1]

By GASTON TISSANDIER.

II.

AT the very moment when Cailletet was subjecting successively to the test of his apparatus the six permanent gases, and was conquering their resistance to compression, M. Raoul Pictet was making his experiments, first on oxygen, then on hydrogen. But what gives a special interest to the labors of Pictet is the fact that he has succeeded in producing a quite appreciable volume of these gases in the liquid or in the solid state. He describes his apparatus as follows:

A and *B* (Fig. 1) are two compound exhausting and forcing pumps, so coupled as to produce the widest possible difference between the pressures of exhaustion and compression. These pumps act on anhydrous sulphurous acid contained in the tubular receiver *C*. The pressure in this receiver is such that the sulphurous acid evaporates at the temperature of −65° C.[2] The sulphurous acid pumped out is carried into a condenser *D*, cooled by a current of cold water; it is there liquefied at a temperature of −25°, and at a pressure of about 2¾ atmospheres. The sulphurous acid returns to the receiver *C* by a small tube *d* as fast as it is liquefied.

E and *F* are two pumps precisely the same as the preceding, and

[1] Translated, with some abridgment, from *La Nature*, by J. Fitzgerald, A. M.

[2] The degrees of temperature here noted are all according to the centigrade scale.

with the same kind of coupling. They act on carbonic acid contained in a tubular receiver *H*. The pressure in this receiver is such that the carbonic acid in it evaporates at a temperature of −140°. The carbonic acid drawn out of it by the pumps is passed into the condenser *K* which is surrounded by the sulphurous acid receiver *C*, the temperature of which is −65° ; it is there liquefied under a pressure of five atmospheres. The carbonic acid returns to the receiver *H* through the small tube *k*, in proportion as it assumes the liquid state.

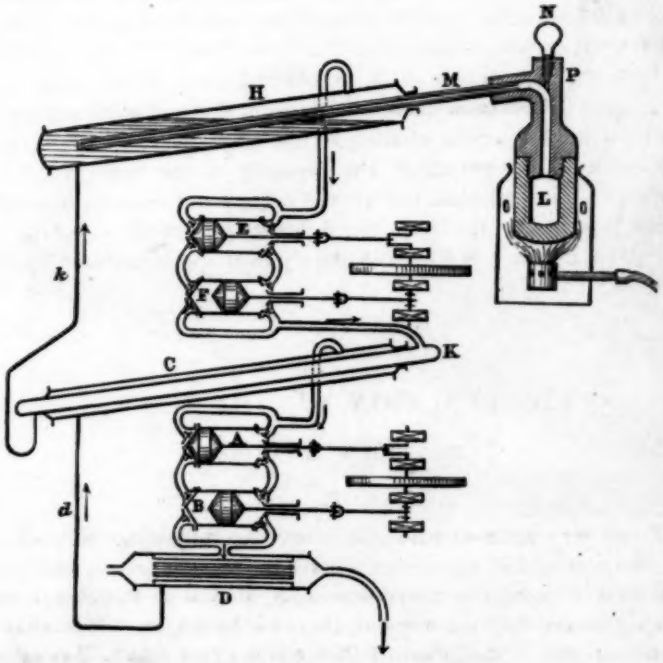

Fig. 1.—Diagram of Pictet's Apparatus.

L is a wrought-iron retort of sufficient thickness to withstand a pressure of 500 atmospheres. It contains chlorate of potash, and is heated so as to give off pure oxygen. It communicates by a tube with a sloping tube *M*, of very thick glass, one metre in length and surrounded by the carbonic-acid receiver *H* whose temperature is −140°. A screw-stoppel *N*, situated above the tubulure of the retort, gives to the latter communication with the external air.

After the four pumps have been at work for several hours, driven by a 15-horse-power steam-engine, and when all the oxygen has been liberated from the chlorate of potash, the pressure in the tube is 320 atmospheres, and the temperature −140°.

On suddenly opening the orifice *P*, the oxygen escapes with violence, producing an expansion and an absorption of heat so great that

a portion of it, in the liquid state, is seen in the glass tube, and spurts out of the orifice on the apparatus being inclined.

A sufficiently clear idea of M. Pictet's method can be had from the above diagram and description; but, as yet, the reader can hardly imagine what the apparatus looks like. Fig. 2 (after a photograph)

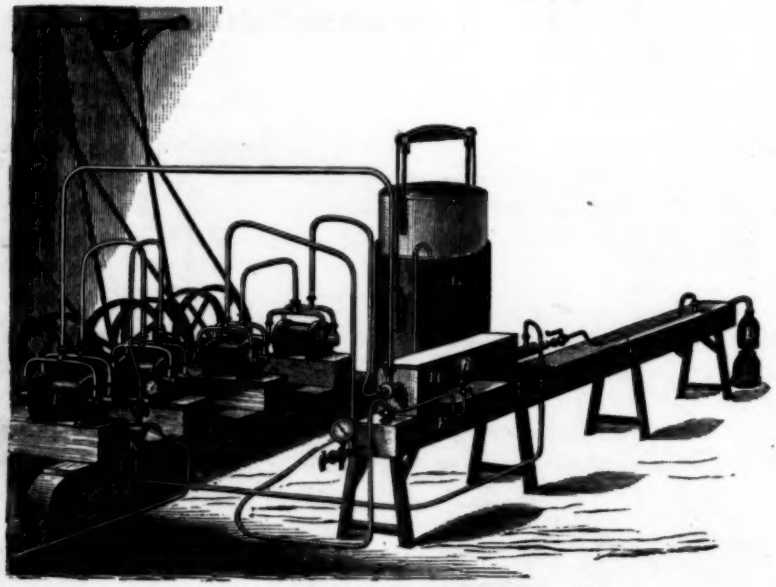

FIG. 2.—PICTET'S APPARATUS (from a Photograph).

and Fig. 3 will supply this deficiency. Fig. 2 is a general view of Pictet's grand liquefaction apparatus, as it stands in his establishment at Geneva; and Fig. 3 exhibits the same in section. This apparatus possesses considerable size; for instance, the head of a man standing would be on a level with the manometer seen near the letter *H* in the engraving.

The perfected apparatus as shown in Fig. 2 differs in sundry respects from the diagram Fig. 1, as will be seen at a glance. One essential difference consists in the arrangement of the liquefaction apparatus proper, Fig. 4. Here *D* is an iron shell (or retort), with walls 35 millimetres in thickness; it contains 700 grammes of chlorate of potash when oxygen is the gas to be liquefied. Its orifice communicates with an iron tube five metres in length, 214 millimetres internal diameter. This tube, bent as in the figure, is closed at both ends, but one end may be opened by means of the cock *E*. A Bourdon manometer, graduated to 800 atmospheres, shows the inside pressure. The tube *c E*, in which the disengaged oxygen is compressed, is completely immersed in liquid carbonic acid, which, by the mechanism of the

pumps before described, enters the apparatus at *a* and passes out as vapor from the orifice *b*, after volatilization.

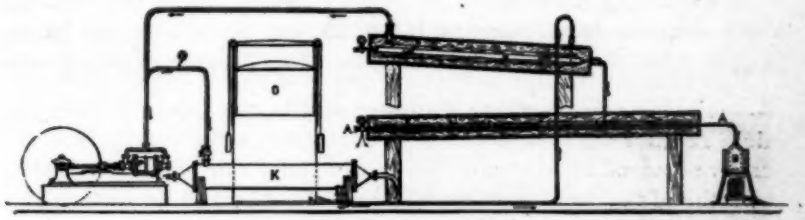

FIG. 3.—SECTION OF THE SAME.

B, cast-iron shell containing chlorate of potash; *A A'*, closed iron tube in which the gas is condensed; *C*, refrigerating cylinder in which liquid carbonic acid is volatilized; *F*, wooden case packed with some bad heat-conductor; *D*, reservoir holding liquid carbonic acid, surrounded by a refrigerating cylinder in which liquid sulphurous acid is volatilized; *H*, case packed with a bad heat-conductor; *G*, gasometer containing gaseous carbonic acid; *K*, reservoir for liquid sulphurous acid; *P*, one of the double-action pumps; *A'*, cock which can be opened so as to give an exit to the liquefied gas which escapes in the direction shown by the arrows.

With this apparatus, M. Raoul Pictet, on Monday, December 24, 1877, in the presence of members of the Physical Society of Geneva, three different times obtained violent jets of vapor which contained globules of liquefied oxygen. On the following Thursday the experiment was made for the fourth time. The manometer, which had risen to 560 atmospheres, after a few minutes fell to 505, and there stood for

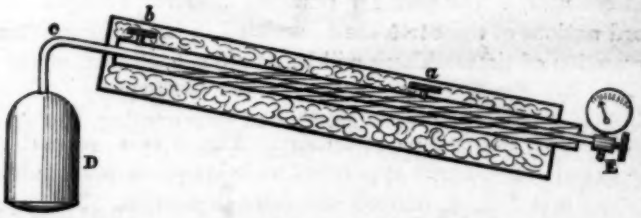

FIG. 4.—THE RETORT AND THE TUBE IN WHICH THE GAS IS LIQUEFIED.

over half an hour, showing by this diminution of pressure the transition of a portion of the gas into the liquid state, under the influence of the −140° temperature to which it was subjected. The cock closing the orifice of the tube was then opened, and a jet of oxygen escaped with extraordinary violence. A beam of electric light, projected on the cone of escapement, enabled the spectators to see that the jet consisted of two distinct parts: the one central, a few centimetres in length, whose white color gave evidence of liquid or even solid elements; the other external, whose blue color showed the return of the compressed and frozen oxygen to the gaseous state.

In later experiments M. Pictet succeeded in collecting a very appreciable volume of liquid oxygen, and in liquefying all the other "permanent" gases.

METRIC REFORM.

By SAMUEL BARNETT.

THE ultimate triumph of the metric system may be regarded as safe, beyond peradventure; no event still in the future is more certain. A universal system of weights, measures, and currency, is an imperative demand of advancing civilization; and this particular solution is worthy of the great problem, fit for all countries and for all time. It has the start, the prestige, the substantial merits, the already large adoption, which insure universality.

Its progress has in many respects been most gratifying. One nation after another has yielded to the arguments in its favor. Dr. Barnard's tables show that in Europe in 1872 France, Germany, Holland, Belgium, Spain, Portugal, Italy, Roumania, and Greece, had adopted it in full; Austria, Denmark, Switzerland, Turkey, Baden, Hesse, Wurtemburg, and Bavaria, adopted metric values, and even conservative England rendered the system permissive. The whole map of Europe is thus riddled—little of it left; the rest is sure to follow. So in North America—the United States, Canada, and Mexico; in South America—New Granada, Eucador, Peru, Brazil, Uruguay, Chili, and the Argentine Confederation; and, among other countries, British India, the French, Dutch, and Spanish colonies, and Japan, are numbered. Thus, nearly all the most advanced nations of the earth are committed to it, and its universality is but a question of time. There will be no steps backward now, but only forward.

All this seems highly satisfactory and encouraging, and it may be asked, "What more could be desired or expected?" But there is another side to the picture.

Among the common people its progress has been as conspicuously slow as rapid among the nations. The statistics of its *actual use*, could they be had, would be heartily discouraging. In some way, and for some reason, upon the common mind it does not *take hold*. Indeed, in a discriminating view, its reception, even among the nations, compares unfavorably with that of many other inventions and devices of modern times: steam, railroads, telegraphy, photography, already cover the earth—all of later date than this system.

With all its admitted merits, the activity of its friends, and the cooperation of governments, the metric system makes no headway among the masses of mankind. As yet but a barren triumph has been achieved; the consent of the government, and not of the people, is the assent of the parents, but not of the maiden. Permission to *woo* is all we have obtained.

Even in France, although the system was provisionally established as early as 1793, and made obligatory, a full generation ago, in 1840,

yet the want of real progress may be seen in the following statement ("United States Dispensatory," Wood and Bache, edition of 1870, p. 1737):

"Though the decimal system of weights and measures was established by law in France, it was found impossible to procure its general adoption by the people, . . . If they adopted new weights, they gave them the names of the old weights. . . . So that three systems are now more or less in use in France—the original *poids de marc*, the decimal system, and the metrical pound, with its divisions."

If such be the case in France, the birthplace of the system, what elsewhere? In the United States its use has been authorized for more than ten years; yet how many business men in the United States avail themselves of their *legal privilege?* How many druggists and physicians? What merchant uses the metre? What surveyor computes in hectares? What farmer measures corn in a hectolitre? Who weighs by kilogrammes, or buys wood by the dekastere?

The words are strange and the things unknown among men of business.

It is worth while to inquire into the impediments. Among these certainly cannot be numbered the merits of any existing system of weights and measures. Take the English tables, for example; they are utterly barbarous—the whole scheme confusion worse confounded; no one defends it as it stands. But there is nevertheless an impediment connected with this *no-system* which has been a serious bar to reform—a vague hope that somehow something might possibly yet be made of it hereafter. This indefinite hope is totally fallacious. There are two tests—the decimal scale, and a proper interrelation of the tables. The English method wants both. Nor can it be altered so as to conform to either.

Take, for example, the leading table of all, long measure, and apply the decimal test; it cannot stand it at all. If you keep the yard, for example, you can keep no other denomination—not one—for no other is decimally related to it; away go the inch, $\frac{1}{36}$ of a yard; the foot, $\frac{1}{3}$; the rod, $5\frac{1}{2}$ yards; the rood, mile, and league; the prime, $\frac{1}{12}$ of an inch; the second and third, the fathom, the chain, link, etc., and all the promiscuous tribe of unrelated units. So it is impossible, if you choose the foot, to keep anything else. Indeed, make your own selection of a unit, and only that selected unit can be retained.

It is the same case with all the other tables; though, instead of *one* table of weights, you have *three*—apothecaries' weight, troy weight, and avoirdupois. Yet, among them all, there is not one single denomination decimally related to any other—not one of the ounces, drachms, scruples, or pennyweights. Even the so-called hundred-weight is not really 100 pounds, but 112.

It grows worse and worse as you study the uncivilized, unkempt system. If the decimal test did not at once and forever dispose of it,

the second test would, viz., hopeless want of proper relations among the tables. Our proper attitude toward the present English tables is that of wholesome and final despair!

Addressing ourselves to the task of reform, we proceed to remark what *the metric system, in substance, will do.* It stands the two tests, perfectly; indeed, it was *made to order* for that very purpose. To provide a system with a proper scale and relations was the work undertaken by Science, and that work has been diligently and well done. Its merits are great and substantial; so full is it of practical utility as well as theoretical beauty, that President John Quincy Adams did not hesitate to pronounce it "a greater *labor-saving machine* than steam itself."

Our object, however, is not to make an argument in its favor, but to inquire into the impediments to its progress. These, though not obvious, are certainly formidable, as is shown by results. There are two sets of conditions to be fulfilled which may be distinguished as the *natural* and the *human* conditions of the problem. The difficulty is not to be found in the non-fulfillment of the former; as has already been remarked, the natural conditions have been well met by Science. But, after all the successful work laboriously done upon these—chiefly in the *verification* of the units—the hardest part of the problem yet remains, viz., such an *adaptation of the system to mankind* that the peoples to be benefitted shall adopt and use it in the daily business of life.

Nor are men of physical science, as such, specially qualified for this task. To adapt the system to man requires a different sort of observation from theirs, for which there are no instruments, but only the patient observation of the ways of this fastidious creature. The huge inertia of this ponderous mass of humanity, as results show, is yet to be overcome. Until this adaptation to man is complete, *the problem is not solved.*

Were a Pacific Railway begun upon the wrong general line, the best remedy would be a change of location. In our present problem the human conditions furnish *guiding principles*—the great salient points of our Pacific Railway—more stubborn than Nature itself. The system is for man—not man for the system; and, if the two do not tally, *it* must yield, not *he!*

What modifications of the metric system are needed to fit it for common use?

Roughly, directness and simplicity. In aiming at these we should study actual human experience. The currency system of America furnishes invaluable guidance. One of its chief lessons is, that *men like not many denominations.*

In our decimal currency, five denominations are proposed—mills, cents, dimes, dollars, and eagles. Of these but two are practically used—dollars and cents. Had the other three been omitted, we should not have missed them.

Look at bank-bills. There is the $10 bill, the $20 bill, the $50 bill. Technically, by the tables they should be bills for 1, 2, 5 eagles. Not so, in fact. Never yet did bank in America promise to pay to bearer, on demand, one eagle! So with fractional currency. You see 10-cent pieces, 50-cent pieces, but none for 1 dime or 5 dimes. Dollars and cents suffice.

"What of all this?" you may ask. Much. It is the embodiment of the ways of men: it is full of practice and suggestion to those who have eyes.

According to the tables, a certain sum is 253 eagles, 5 dollars, 4 dimes, 6 cents, 3 mills. Never was it so called. What says our curt mankind? 2,535 dollars, $46\frac{3}{10}$ cents. The mind *scants* denominations. It seldom uses *more than two*, if it can help itself.

On broad principles, indeed, it might be asked, "*Why have denominations* at all?"

Number, whole and decimal, with one unit for each subject-matter, is *adequate to express any quantity whatever.* No second denomination is *essential* in any table. Any weight, for example, can be expressed in pounds and decimals of a pound, without reference to other units. The largest quantities can be so expressed, and the smallest. In currency we express a national debt reaching to billions in the self-same unit which is used for small daily transactions, say in dollars or in francs. This shows the unlimited capacity of number for exact expression without any table of denominations at all.

Indeed, in England and America it may safely be said that *a single denomination in each table would be better than the present method* with its irregularity and confusion, better for mental grasp of the quantity expressed, and better for calculation. A clearer idea is obtained by the expression 13,518.6 lbs. than by its equivalent in numerous denominations, 6 tons, 13 cwt., 3 qrs., 17 lbs., 11 oz., 5.6 drachms.

We would not be understood to limit a system to one denomination, or even to two. Yet *two* well-chosen units in each table, as compared with the present English system, would be a decided improvement. Suppose we had pounds and *pound cents*, yards and *yard cents*, etc., corresponding with the dollars and cents of currency; they would furnish incomparably superior advantages to the existing methods.

We will not, however, discuss the exact denominations needed for each table, and the maximum and minimum for each; nor the scale, whether it should be strictly decimal (a denomination for every 10), or one for every 100 (the cental scale); or *eclectic*, varying with the subject-matter. We will, however, remark that in nearly every table the number of denominations can be reduced, not only safely, but advantageously.

Our object, however, for the present is to suggest principles, not to elaborate details; too many denominations perplex, instead of aiding, the mind.

Besides the *units* of a system, the *names* are to be considered; this leads us to by far the most important subject of discussion—

Nomenclature.—Let us with this begin a lesson derived from the actual observation of human habits. The case of the French has been already cited: *they adopted the new units, but rejected the new names.* This is very suggestive. In the United States a similar instance occurs in the names of coins. We still have, in many parts of the country, shillings, sevenpences, thrips, etc. In New Orleans we get *bits* in change. In the great commercial city of New York prices are still given, and goods marked, in shillings, viz., 6 shillings a yard, not 75 cents; ten shillings, not $1.25.

What is the lesson from all this? Plainly, that *new words* are harder than *new things.* How much easier, too, were the names of the new coins than the long and learned names of the metric nomenclature!

"None of your Latin for me!" begs the Frenchman, unfamiliar with that tongue. "Especially, none of your Greek! It is enough if I accept your units; pray excuse me from your names." And even the French Government, which attends to everything, has had ill success in this. The Englishman finds in French forms and accents additional impediments. Unless corrected, he would, to begin with, *mispronounce* fully half the words; knowing barometer and thermometer, he would be sure to say "ki-*lom*-e-tre" also.

Seriously, it were easier for the learned to acquire a nomenclature founded on Hottentot and Sanskrit, dressed off in Kamchatkan forms, than for the unlearned to acquire one in Latin and Greek with French forms; the learned have some familiarity in dealing with new languages to start with. The metric words are *ferœ naturæ* to all people, and will not domesticate. To the common people they are simply *outlandish*, and "neither have the accent of Christians, nor the gait of Christian, pagan, nor man."

Broadly, a system of weights and measures furnishes no case for learned nomenclature. The system is intended for wholly untechnical uses and people, while the words are adapted only to the learned, and even for them are too stiff for daily use. It is clearly a case for easy and familiar names.

More results hinge on the nomenclature than on any other feature of the system; yet it has received little real discussion; it has been simply taken for granted on its looks and outside. Indeed, it has been the boast and pet of the whole metric system, unsuspected as really the chief clog upon its progress. Brought to the tribunal of fair criticism, it is thoroughly unphilosophical, and needs to be remodeled in the light of modern investigations into the first principles of language, all of which principles it violates.

Take the first word of the first table—millimetre—*without explanation, aliunde*, it conveys no information even to a learned man. *Metre* is merely *a* measure, not any *definite measure*, not even necessarily a

measure of length. Nor does it at all, of its own force, tell how long.

Milli, the prefix, means a thousand ; but by explanation, not by its own force, is made to indicate the $\frac{1}{1000}$ part. After both these explanations, leave the most learned man alone with it, and he is entirely at a loss as to the actual length of the $\frac{1}{1000}$ part of a metre. He can form an idea of a half, a fourth, or other like fraction, but of the $\frac{1}{1000}$ part none, unless by a long process, or by being told.

Again, the nearer alike things are, the greater the difficulty of distinguishing them. Every one has observed how hard it is to recognize people in uniform. Upon this obvious principle *the* UNIFORMITY *of the metric names in sound and general aspect* is a serious practical hinderance. To an Englishman they are like a party of foreigners : they all look and jabber alike; he can hardly tell them apart.

It is unfortunate that in the metrical household every family has the same Christian names. We can imagine some wag proposing middle names just to break up the monotony. When you hear *deci*, your active mind, always anticipating, calls up a member of each family, and you think of deci-gramme, deci-metre, deci-arc, deci-stere, and deci-litre.

All this is diametrically wrong. Really, one is tempted to remark that the metric nomenclature got, indeed, upon exactly the right road, but took exactly the *wrong end* of it. It struck out toward the hard, the learned, the abstract, instead of the easy, familiar, and concrete. Observe how terse and expressive, and how perfectly *distinct* and unlike, ordinary words are—God, man, world—each freighted with meaning, and, in English, all frequently in one strong syllable. Take the objects in this room—desk, books, chairs, sofa, pen, ink, paper, knife—how thoroughly unlike, how instantly expressive, and nearly all monosyllables!

The great trouble with these metric words is that they will not *nick ;* otherwise *myriametre* would cast a syllable a day, and soon become short and easy. That is a way the English have. But these words will not nick at either end, head or tail. Ingenious efforts for *nicking* have been devised by Prof. McVickar and others, which may help men of learning; but they presuppose too much familiarity already for common people.

And, after all, the true point has been missed, which is not sameness of *words*, the world over, but merely sameness of *units ;* the object being not to save *translation*, but to save *calculation*. Even natural units need translation, and the artificial units we devise might be content to get on a footing with natural ones. How small a purpose, indeed, would be served if the names of the measures were the same, but of the numbers not the same, nor of the things measured! Such are some, by no means all, of the incurable faults and defects of the metric nomenclature.

The obstacles to metric reform have been chiefly artificial. Like

little David in Saul's armor, the system has been weighed down with superfluities. A simple illustration may be given of its highly artificial character. A sufficient table of currency would be—

100 cents make a dollar.

What would this become, subjected to nomenclature? For dollar, we should have to substitute some Greek word, say *argurion*, or *argur*. But give the benefit of familiarity by keeping the word dollar, the above table, *metricized*, would assume this form:

10 millidollars make a centidollar.
10 centidollars make a decidollar.
10 decidollars make a dollar.
10 dollars make a dekadollar.
10 dekadollars make a hectodollar.
10 hectodollars make a kilodollar.
10 kilodollars make a myriadollar.

What is needed?—The utmost simplicity and straightforwardness. The system should carry no dead weight. Starting with no superfluous units, these units need—

Names.—And here comes in the process of "conscious word-making," the conditions of which have only recently been much studied. The department of science which qualifies men to suggest suitable names or principles for their selection is not physical but linguistic.

The *extraordinary vitality of old words* was observed by Lord Bacon with his usual practical sagacity. Even in philosophy, addressed to the learned, he remarks, "I am studious to keep the *ancient terms* . . . though I sometimes alter the uses and definitions." Again, with unwonted earnestness (still referring to language), he declares himself "*zealous and affectionate* for antiquity." Taking pains to explain the modifications of meaning, he retained *ancient terms*, knowing how bewildered men become with a strange vocabulary, especially when, as in the metric nomenclature, a great batch of new words is thrown upon them at once—long and strange, and slow to yield their meaning.

These sagacious anticipations of Bacon have been abundantly confirmed by modern observations. Prof. Whitney, whose works exhibit great good sense and clear-headedness as well as ample learning, uses such expressions as these, showing the habits of mankind in the formation of words, "Stretch a familiar name to cover it;" i. e., a new idea. Again, he speaks of "new applications of old (word) materials," and of "the short cuts" which language frequently makes.

One pregnant sentence we will quote in full: "We have had to notice, over and over again, the readiness on the part of language-users to forget origins; to cast aside, as cumbrous rubbish, the etymological suggestiveness of a term, and concentrate force upon the new and more adventitious tie."

How much "cumbrous rubbish" impedes the metric names!

The principle on which names should be given is sufficiently clear. The names should simply answer the natural questions: "How long is it? How big square? How heavy?" etc.

To illustrate by long measure—the base-unit is now called the metre—"How long is that?" is the first question. A *pace*, a long *step*, a *stride*, would answer the question; probably, in England and America, despite all objections, a *new yard*, or a *long yard*, is the best name. The *new* would be dropped in due time (as in new style and old style), and the name becomes simply *yard*.

To proceed with the table. Each and every unit in each table should have its own *strong, independent name*, instead of a name referring to the base-unit, so called. The actual relation between the units is important; but to express this in the name is worse than superfluous, it is a mere incumbrance. *There is no danger of forgetting the decimal scale.*

The metric tables provide names for—

$\frac{1}{10000}$, $\frac{1}{1000}$, $\frac{1}{100}$, $\frac{1}{10}$, 1, 10, 100, 1,000, 10,000 metres.

Some of these we would omit, and perhaps provide others not given, beginning with the $\frac{1}{10000}$ part, for microscopic uses.

What should the name be? It should *suggest* the length intended, say, a hair's-breadth, or a leaf's-thickness; soon, by shedding, a hair or leaf.

The name of the $\frac{1}{1000}$ part? Still suggestion—say, a pin's-breadth (soon, a pin), a straw's-breadth, a narrow braid, a coin's-thickness, or a card's or knife-blade's. The words "breadth" or "thickness" would serve the purpose of explanation at first, and then shed, leaving only pin, straw, braid, knife-blade, card, etc.

Some such name would serve—*not*, millimetre in Latin and Greek; *not*, even metre-thousandth in Greek and English; *not*, any name expressing a *numerical* relation to some other unit. If any numerical relation at all, *not* to a unit at 1,000 removes. Finally, not a fractional relation, if any, but one expressed by a whole number. All these *negative limitations* are full of matter.

The next name—the $\frac{1}{100}$ part—might be nail's-breadth, nail.

The next, now decimetre, hand.

Then, the new yard, or long yard, finally to become yard.

The fifth unit, 10 metres, half-chain. Really no name needed.

100 metres = stone's-throw; bow-shot = throw, cast, shot.

1,000 metres = a short mile, new mile. An accidental association would make the word *kile* serve. The learned would know the Greek derivation; the unlearned would remember it by the rhyme. Numerous illustrations occur, equally casual. The objection is not to Greek, but to the want of some familiar association, no matter how trifling.

10,000 metres = a great league, or double league.

Observe that each unit thus named is as much a *base-unit* as any other.

Had the units of the old English system been properly related, the names were all right. Each name could *stand alone!* Twelve inches did not make one "*duodecem unciæ*," but *one foot;* three feet, not the Latin for three feet, but a terse English word, one yard (i. e., a shoot or switch—the first yard-stick). Five and a half yards made (the *scale* being all wrong, but the name all right) one rod, pole, or perch.

The following brief table might approximate to a sufficient one for linear measure:

100 hair's-breadths make 1 nail's-breadth.
100 nail's-breadths make 1 long yard.
1,000 long yards make 1 kile.

Soon to dwindle to this form:

100 hairs make a nail.
100 nails make a yard.
1,000 yards make a kile.

For astronomical purposes we might add:

10,000 kiles make 1 great quadrant.

Of course, the above names are not suggested as final, but only as illustrative. Again, the actual lengths would be perfectly definite, and the modes of verifying fixed by science.

If any object to the omission of the millimetre, how easy to say ten hairs! The cental scale usually suffices—witness "ten cents" *vice* a "dime."

Ah! but how meagre and shabby is this in comparison with the beautiful and learned nomenclature, with its long words, rolling *ore rotundo* from learned lips!

Alas! that system is too pretty for use—like a mowing-machine, gilded and decorated, which cuts too high, and passes *above its work*, leaving no grass in its trail. This humble blade is intended to *cut low;* it must even scrape the ground, and rake the very dust, rather than *not mow*. Plain, ignorant people are to be reached; children, servants, the dullest plodders, are all to use whatever names we adopt. We do well to be humble. The lofty, high-sounding names heretofore proposed have gained no currency; they have been "*stifled by general neglect.*"

But how about universality?

A ready means for this is found in *notation*.

Universal symbols are as easy as a universal nomenclature is difficult. Take, for example, the nine digits. Englishmen, Frenchmen, Germans, Japanese, look at the figure 3; they call it by different names, each in his own mother-tongue, but they all think of the same thing. The *thing*, the *thought*, the *mark*, are all the same—the *words* differ. So is it with the notes in music, the symbols in algebra and geometry, etc.

A notation may be devised which addresses the eye, and is self-ex-

planatory. The base-units may be represented, for example, as follows:

That of length, by a straight line, graduated, to distinguish it from *minus*.

Surface, by a	square.
Solid	cube or block.
Capacity	cup.
Weight	pound-weight.
Money	coin, stamped.
Angle	two lines, meeting.
Time	waving line.

We only suggest, and do not expand.

The substance of the foregoing suggestions, summed up, is as follows:

Adhering to the metric system as a basis—its modification by the following features:

1. The entire abandonment of the present elaborate and ingenious system of nomenclature, and of any attempt at universality in the *words* employed to designate the units of the system.

2. The expression of each unit by each nation in its own vernacular tongue—the units themselves being the same everywhere, but the expression in language adapted to the familiar tongue of each people.

3. A common notation as the means of universality, instead of a common system of names, the units and their *written* expression being thus universally the same, while the spoken expression conforms to familiar national usages.

4. The words selected to express the several units to be suggestive of easy standards of comparison with familiar objects.

5. The *notation* also to be suggestive to the eye, as the nomenclature heretofore in use was to the learned ear, but not to the unlearned.

6. The number of denominations to be reduced in conformity with an observed tendency among men to use numbers instead; oral expression to be simplified; and a suitable actual system of notation suggested.

7. The transition to the new system to involve the least practicable loss of familiarity—either with familiar *objects* or familiar *names*.

These modifications adapt the metric system to the needful human conditions. Accepting its solutions of the natural conditions, they conserve all that is really valuable, and reject only what is cumbrous. The metric nomenclature is quite as unphilosophical as the English scales; both are fit only for decent burial. The real desideratum is to reduce to a minimum the difficulty of introducing the new units. Can the transition be better effected than on the foregoing principles?

This ponderous and scattered human family—a huge class of grown pupils, not gathered into school-room, nor used to formal instruction—

complains of its lessons; it begs for a less task. We propose to excuse you from your Greek and your Latin, and from French forms, from long words and hard names, from the queer pronunciations and the wrong accents. We let you off from half the units, perhaps two-thirds, and furnish you with familiar standards of comparison for those which are left, and give you English names to boot—Anglo-Saxon when possible, short, terse, and significant—though we take care, on our part, to have them properly related, not leaving that matter to you.

What! not yet satisfied? Unreasonable mankind! let us convince you that this is the least cost you can pay, and insure the desired benefit.

Scarcely another so important reform awaits the human family. But it will not take care of itself. We have referred to two aspects of progress—progress among governments, want of progress among the people. The latter is incomparably the more important. The one is semblance, the other substance. Until the metric system is used, it is not a labor-saving machine for service, but a mere toy to look at—an anticipation, a dream, not a reality and a possession. And such it is now.

We must not rely on a change in human nature, but must adapt our system to it; otherwise, indeed, mankind may, perhaps, in the distant future, wear out to the system, like a Chinese foot to a shoe. Should we await this slow and painful process, or should we not rather adapt the shoe to the foot?

Can we look forward to a time when these long foreign words shall be as familiar to every child in Christendom as the words foot, yard, bushel, pound, now are to English ears? And yet this is the proper standard of familiarity; it must be absolute and unhesitating. Do the long words, indeed, deserve to be as familiar? Are they formed to be? No; we must reach the mother-tongue of each people.

Nor can we afford to wait, to bring the matter home.

Can the English and American peoples—the two most commercial peoples on the globe—be content, on the one hand, with permanent isolation, founded on inferiority? or, on the other, can they ask mankind *to accept* their system, forsooth, as worthy of universal use? Will England, for example, ask America to return to *£ s. d.* and *qrs.?* Or America, for very shame, present her compound reduction tables for the admiration and universal adoption of all nations?

Let not the friends of metric reform be deceived with vain hopes. Government work, and the work of colleges and schools and scientific associations, all put together, are not equal to *adaptation!*

THE QUESTION OF PAIN IN DROWNING.

By ROGER S. TRACY, M. D.

EVERY one has tried the experiment of "holding the breath," and has found that after the lapse of a minute, or a minute and a half at the farthest, there supervenes a most peculiar and intolerable kind of anguish. Nature then takes the management of the lungs out of our hands into hers, and we breathe in spite of ourselves. The distress felt at such times we think of when we read of a death by drowning or hanging; and, although it has been asserted over and over again that such a death is painless, hardly any one really believes it. And yet I think it can be shown not only that drowning and hanging *are* painless modes of death, but *why* they are so.

When a person, who cannot swim, falls into deep water, he is seized with a sudden and tremendous fright. The exceptions to this rule are too few to be worth noticing. This fright, of itself, kills some persons, and they go to the bottom like a plummet. Women are very apt to faint, and, as they sink beneath the surface and respiration still goes on involuntarily, they probably drown before they regain consciousness. Plethoric persons, or those in whom the degenerative processes of old age have weakened the coats of the arteries, may have a stroke of apoplexy, partly from the sudden emotional shock, and partly from the chill of the water, which, by driving the blood from the surface, overfills the vessels of the internal organs. In fact, it is estimated by Taylor, in his "Medical Jurisprudence," that of all drowned persons twenty-five per cent. die of pure asphyxia, and in the remainder the asphyxia is complicated by syncope and apoplexy. The chances are, then, three out of four, that a person who falls into the water and drowns will die a painless death, because he becomes insensible on the instant. But what about the remaining fourth?

In the first place, it is to be remarked that persons who have come so near drowning as to be unconscious when taken from the water, and so must have passed through all the suffering that attends death by drowning, say that they remember no feeling of pain whatever. This declaration must have great weight, for it is not to be supposed that they could forget such terrible distress as that which follows when the respiration is suspended voluntarily. They all describe their feeling much in the same way: "I remember falling into the water. It was dreadfully cold. I felt my clothes clinging about me and hampering my movements, and as I rose to the surface I gasped for breath. My mouth was filled with water, and I sank again. I was chilled through and through; then a sort of delirium came over me, and there was a ringing in my ears. I remember nothing more." The last symptom

mentioned immediately precedes unconsciousness, as all who have taken anæsthetics know.

It is probable that the entrance of water into the lungs has a great deal to do with the painlessness of drowning. It is certain that unconsciousness comes on more quickly when the person is deprived of air because the lungs are filled with water, than when the air-passages are closed, while the lungs remain intact. Most persons can hold their breath for a minute, very many for a minute and a half, some for two minutes. In one of the variety theatres of New York appeared recently "The Brilliant Pearl of the Enchanted Grotto, christened Undine, who performs, while under water, incased in a mammoth crystal illuminated glass tank, feats of astonishing suppleness and almost unbelievable endurance." This performer can probably remain under water, holding her breath voluntarily, two minutes and perhaps more. I have myself, watch in hand, seen Johnson, the celebrated ocean-swimmer, remain under water, in a tank before an audience, for the astonishing space of three minutes and twenty seconds, and, before he rose, the involuntary contractions of his respiratory muscles were uncomfortable to witness. In such cases, although extreme distress may be felt, there is no approach to unconsciousness. But if a person's head is under water, and he does not hold his breath, unconsciousness will usually come on in one or two minutes at the farthest.

If this be so, it is evident that a person will drown more quickly if he loses his presence of mind on falling into the water than if he retains it. In the former case he will swallow water with his first gasp after sinking, while in the latter case he will hold his breath as long as he can. The latter will suffer more than the former. There is also a difference in the amount of mental agony in the two cases. A person who cannot swim sinks at the first plunge, but, as soon as the impetus of his fall is destroyed, his frantic struggles or a kick against the bottom, if he happens to touch it, sends him up to the surface, for the specific gravity of the body is so nearly that of water that a very slight motion of the hands or feet is sufficient to keep one afloat. Arrived at the surface, he gasps for breath, swallows a quantity of water, sucks some of it into his lungs, catches hold of straws or small floating objects in a wild, senseless way, and, every time he lifts his arm above the surface, produces the same effect as if a piece of lead had been tied to his feet. So down he goes again half strangled, and the same process is repeated. As soon as unconsciousness comes on, the struggles cease, and the body remains beneath the surface. During all this agony the suffering of the drowning man is undoubtedly chiefly mental. It comes from the instinctive dread of death which even the stoic cannot rid himself of, and is of the same nature as the mental agony of the condemned man before his execution, though less prolonged. And it is probable that even this mental suffering is so much affected by the convulsive and tremendous physical agitation that, in a measure, the

two counteract each other, and the drowning person, from the moment he strikes the water, is hardly conscious of what is going on.

A swimmer, or a person whose presence of mind enables him to keep his head above water for some time before drowning, passes through a different experience. But, although data are wanting on this point, it is probable that his final agony is short and painless. His physical exertions, kept up for a long time in the hope of relief, together with his exposure to cold and wet, and the lack of nourishment, combine to reduce his strength very rapidly, and it is not altogether a conjecture to suppose that a single draught of water into the lungs, when he finally gives up, is enough to bring on unconsciousness. His suffering, too, is chiefly mental, but he experiences the additional discomforts of exhaustion, cold, and hunger, if his struggle for life is a prolonged one.

It is believed that the rapidity and painlessness of death by drowning are due chiefly to the speedy obstruction of the circulation of the blood through the lungs. In ordinary asphyxia, by the simple deprivation of air, the blood throughout the body becomes charged with carbonic acid, and the arteries as well as the veins become filled with venous blood. Now, venous blood does not pass readily through the capillary vessels, and, when the accumulation of impurities has become so great as to prevent its passing at all, the circulation comes to a standstill. But the dreadful distress of suffocation comes on long before this point is reached. Now, when cold water is sucked into the lungs and comes in contact with their delicate and sensitive mucous membrane, it must cause an instant and powerful contraction of the capillaries, and obstruct the current of blood from the right side of the heart, thus indirectly damming back the venous blood in the brain. This state of things brings on unconsciousness rapidly, preceded by the pleasurable tingling sensations, rapid succession of ideas, and flashes of light and color, so often described by persons who have been rescued from drowning.

Drowning persons, then, die in different ways:

1. By syncope, and asphyxia while unconscious. Some of these die instantly.

2. By apoplexy (usually congestive), common in plethoric and aged persons, followed by asphyxia while unconscious.

3. By asphyxia pure and simple.

Deaths which come under the first two heads are rapid and painless, constituting probably a half, and, according to Taylor, three-quarters of all deaths by drowning.

Deaths which come under the third heading we presume are not accompanied by physical suffering for these reasons:

1. Persons who have been resuscitated, after having become unconscious, declare that they have felt no pain whatever.

2. Death is speedy.

3. Persons who lose their presence of mind are so occupied with

their struggles and mental agony that a slight degree of physical pain would be unnoticed.

4. Swimmers, and persons who do not lose their wits, become so exhausted and chilled that, when the final act comes, their powers make but a feeble resistance. And, in both cases, the passage of water into the lungs tends to bring on insensibility by obstructing the circulation, before it is time for the agony of asphyxia to be felt.

So that, in drowning, we have reason to believe, contrary to Taylor's opinion, that pure, uncomplicated asphyxia never occurs.

If death by drowning be inevitable, as in a shipwreck, the easiest way to die would be to suck water into the lungs by a powerful inspiration, as soon as one went beneath the surface. A person who had the courage to do this would probably become almost immediately unconscious, and never rise to the surface. As soon as the fluid filled his lungs, all feelings of chilliness and pain would cease, the indescribable semi-delirium that accompanies anæsthesia would come on, with ringing in the ears and delightful visions of color and light, while he would seem to himself to be gently sinking to rest on the softest of beds and with the most delightful of dreams.

SCIENCE AND MENTAL IMPROVEMENT.[1]

By Professor JOSEPH LE CONTE.

THIS club, as I take it, was formed for mutual improvement. The narrowing and ever-increasingly narrowing tendency of professional pursuits, in these modern times of division of intellectual labor and eager struggle for life, renders the formation of such associations very necessary. The ideal of a life-culture, as I conceive it, i. e., of a culture which, commencing with youth, shall terminate only with death, is briefly epitomized as follows: First, a general culture of all the faculties—a preparation for general efficiency without reference to any special pursuit—to the period of full maturity; then a concentration of the thus strengthened and disciplined powers upon special professional studies, but still in connection with a scheme of liberal culture or university, by which the professional culture shall be impregnated with the lofty spirit of liberal learning; and, lastly, when active professional life commences with its necessary narrowing effects, the formation of associations like this, by which we are brought into contact with the best thought in every department.

If culture be the object of your association, then ought it *not* to be merely an association of *kindred spirits*, as many think. On the contrary, it should consist of persons of the most diverse pursuits—theologians, lawyers, physicians, engineers, merchants, and of all modes of

[1] An address before the Chit-Chat Club in San Francisco.

thought, from orthodoxy to rationalism, from idealism to materialism, from old-fogyism to young-Americanism—with one condition only, viz., that all be imbued with the spirit of liberal culture. Now, among the pursuits which ought to be represented here, I believe none to be so necessary as that of science; and for the reason that the spirit of science and the methods of science are more diverse from the spirit and methods of other intellectual pursuits than these latter are from each other.

I will say nothing of the glorious achievements of science already set forth in the sentiment to which I am called to respond; nor even of science as a means of mental discipline, for this would take too long. I wish only to remove some objections which have been brought by her detractors against Science as an agent of general and liberal culture; for it is with this that your association is chiefly concerned. Among these objections, however, I select only one, but perhaps the chief, viz., the tendency of science to materialism. It is believed by many that science starves all our noblest faculties, quenches all our most glorious aspirations, and buries all our heavenly hopes in the cold earth of a vulgar materialism.

Now, it is indeed true that there has been in these modern times a strong tendency, a current of thought, in the direction of materialism. It is true, too, that this tendency is strongest in the domain of science, and, among sciences, strongest of all in biology and geology; but I believe it is true also that this is only a passing phase of thought, an ephemeral fashion of philosophy. As a sympathizer with the age in which I live, still more as a scientist, and most of all as a biologist and geologist, I have felt the full force of this tendency. In this stream of tendency I have stood, during all my active life, just where the current ran swiftest, and confess to you that I have been sometimes almost swept off my feet. But it is the duty of every independent thinker not to yield blindly to the spirit of the age, but to exercise his own unprejudiced reason; not to *float* and *drift*, but to *stand*. I think I can show you that materialism is not the necessary outcome of scientific studies and the scientific spirit. For this purpose, I will select that scientific theory which is supposed to be *par excellence* materialistic, viz.: the theory of evolution. I wish to show that even evolution does not necessarily lead to materialism, and that to conclude so is a very shallow view of the subject.

First of all I wish frankly to acknowledge that I am myself an evolutionist. I may not agree with most that evolution advances always *cum æquo pede*. On the contrary, I believe that there have been periods of slow and periods of rapid, almost paroxysmal, evolution. I may not agree with most that we already have in *Darwinism*, the final form, and *survival of the fittest*, the prime factor of evolution. On the contrary, I believe that the most important factors of evolution are still unknown—that there are more and greater factors in evolution than are dreamed of in the Darwinian philosophy. Nevertheless, evolution is a grand

fact, involving alike every department of Nature; and more especially evolution of the organic kingdom, and the origin of species by derivation, must be regarded as an established truth of science. But, remember, evolution is *one* thing and materialism *another* and quite a different thing. (The one is a sure *result of science;* the other a doubtful *inference of philosophy.*) Let no one who is led step by step through the paths of evolution, from the mineral to the organic, from the organic to the animate, and from the animate to the rational, until he lands logically, as he supposes, into blank and universal materialism—let no such one, I say, imagine for a moment that he has been walking all the way in the domain of science. He has stepped across the boundary of science into the domain of philosophy. Yet the step seems so easy, so natural, so inevitable, that most do not distinguish between the teachings of science and the inference of philosophy, and thus the whole is unjustly accredited to science. Now, as most people not only do not make, but have never imagined, any such distinction, I am anxious to make it clear to you. This I can best and most briefly do by some simple familiar illustrations.

It is curious to observe that no sooner do we find out, in any work of Nature, *how* it is made, than we all say that it is not made at all; it made itself. (So long as the origin of species was a mystery, every one admitted that species must have had an intelligent Maker. But no sooner did we discover the process, than every one seemed to think that no Maker is necessary at all.) Now, the whole object of science is to discover *processes* by which things are done; or *how* things are made. Is it any wonder, then, with this perverse tendency of the present mind, that science should ever and anon seem to destroy belief in a Supreme Intelligence?

Again, it is curious to observe how an *old* and familiar *truth*, coming up in a *new form*, startles us as an impossible paradox. I well remember some twenty-five years ago, when the little instrument the gyroscope first made its appearance, how it startled everybody by its seeming violation of the laws of gravity. Imagine a heavy brass wheel rotating rapidly at one end of an axle, while the other end is supported on a vertical column. So long as it rotated, the heavy wheel, instead of falling, remained suspended in mid-air, revolving meanwhile slowly about the point of support at the other end of the axle. At first sight it seems as wonderful and as paradoxical as the body of Mr. Home, the spiritualist, sailing in mid-air in full view of his gaping and noble audience. In the case of Mr. Home, we suspect some mistake or deception; but there is no mistake about the gyroscope. Yet this strange paradox, which startled people so, and which so flooded scientific literature with explanations, is an old familiar fact in a new form. The problem is precisely the same as that of the *boy's top*, which spins and leans, and slowly revolves in its leaning, but does not fall so long as it continues to spin.

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Now, in evolution, also, we have no *new* truth, but only an *old* truth in a *new form:* and lo! how it startles us out of our propriety! *The evolution of the individual* by a slow process from a microscopic germ. Everybody knows this. Yet it has never heretofore interfered with a belief in an intelligent Maker of each of us. Perhaps most of you may remember, when first at your mother's knee, you were asked, "Who made you?" and you answered as you were taught, "God made me." But suppose you had asked in return, "How?" The only true answer would have been, "By a process of evolution." Yes, every one of us was *individually* made (and is not this far more important for us individually than any origin of species, even of the human species?) by a slow process of evolution from a microscopic spherule of unorganized protoplasm—the germ-cell. Yet the knowledge of this fact did not make us ridicule the reverent answer of the little one, or despise the pious teachings of the mother. Why, then, should it be different in this case of the origin of *species* by evolution?

Again, all vexed questions are such, because there is truth on both sides. Unmixed error does not live to plague us long. Error lives only by virtue of a contained germ of truth. In all vexed questions, therefore, there are three views, viz., two opposing, partial, one-sided views, and a third, more rational and comprehensive, which combines and reconciles them.

I can best illustrate this by the familiar story of the fabled shield. You well remember how, in the good old times of knight-errantry, this shield was hung up in the sight of all men in token of the fact that the owner challenged the world to mortal combat. You well remember that the shield having been seen by many knights, these knights, on comparing notes, could not agree as to its color, some declaring that it was *white*, and some equally certain that it was *black*. You well remember that after many lances had been splintered, after many broken heads and bloody noses had been endured in the vain attempt to settle this *vexed question*, by the blundering logic of blows and knocks, as was the fashion in those days (alas! do we not even now settle many questions in the same way, only we call the process now, the "*logic of events*")—after, I say, many blows had been given and taken in the sacred cause of truth, some one who, strange to say, had something of the spirit of science, and who, therefore, thought that truth was to be discovered, not by conflict, but by *observation*, proposed that the shield be examined. The result you all know—*one side was white and the other was black.*

Now, do you not observe that both parties in this dispute were right and both were wrong? Each was right from *his* point of view. Each was wrong in excluding the *other* point of view—in imagining *his* truth to be the *whole* truth. And do you not observe also that the true view combined and reconciled the two partial views? There is an old adage that "truth lies in the middle," between antagonistic ex-

tremes. Now, while there is a kind of truth in this adage, yet, as usually understood, I believe it contains a most pernicious error. It is the favorite adage of the timid man—the trimmer, the time-server, the politician, the fence-man. Suppose there had been present on this occasion one of these fence-philosophers. He would have reasoned thus: "These gentlemen are of equal intelligence, equal veracity, and equal *strength* (a most important element in making up an opinion for these fence-men); the one says the shield is white and the other says it is black; now, truth lies in the middle: therefore I conclude that it must be a kind of gray or neutral tint, or perhaps a sort of *pepper-and-salt*." Do you not observe that of all the crowd he is the only one who has absolutely no truth in him? No, gentlemen; truth and rational philosophy is not a mere *mixture* of opposing views—truth is *not* what our English friends might call a philosophic "'alf-n'alf." It is rather to be sought in a more comprehensive view, which combines and reconciles opposing partial views—it is a stereoscopic combination of *two* partial surface views into *one* objective reality.

So is it, gentlemen, with many vexed questions; so is it with the question of *origin of species*. There are three possible views in regard to the origin of species. The first asserts Divine agency by *miraculous* creation, and therefore denies any *process;* the second asserts *evolution-process*, but denies Divine agency; the third asserts *Divine agency by evolution-process*. So, also, are there three corresponding views in regard to the origin of the individual—of you, of me, of each of us. The first is that of the little innocent, who thinks that God made him as he (the little innocent) makes *dirt-pies;* the second is that of the little hoodlum, who says, "I wasn't made at all, I growed;" the third is the usual adult belief—that we are made by a process of evolution. Do you not observe, then, that in the matter of the origin of species many good theologians and pietists are in the position of the little innocent? They think that species were made *without natural process*. On the other hand, most evolutionists are in the position of the little hoodlum; for they think that species, *because they "growed," wern't made at all*. But there is a higher and more rational philosophy than either, which holds that the ideas of *making* and of *growing* are not inconsistent with each other—that evolution does not and cannot destroy the conception of, or the belief in, an intelligent Creator and Author of the cosmos. This view combines and reconciles the two preceding antagonistic views, and is therefore more comprehensive, more rational, and more true. But let us not fail to do justice—let us not overlook the fact that the most important and noblest truths are overlooked only by the hoodlum and materialist. *Of the two sides of the shield, the little innocent and the pietest sees, at least, the whiter and more beautiful.*

The end and mission of science, gentlemen, is not only to discover *new truth*, but also, and even more distinctively, to give *new and more rational form to old truth*—to transfigure the old into the more glorious

form of the new. Science is come, *not to destroy*, but, aided by a rational philosophy, *to fulfill* all the noblest aspirations, the most glorious hopes of our race. Sometimes, indeed, the change which she brings about may be like a metamorphosis: the useless shell is burst and cast off, and a more beautiful and less gross form appears, but still it is always a process of evolution—of derivation. We never shall reach a rational philosophy until we recognize this fundamental truth. The *new* must include the *old*—the old must incorporate and assimilate the new, and each must modify and be modified by the other. Progress in all things—in geology, in society, in philosophy—is *by evolution and growth;* not by *successive catastrophes* with alternate destructions and recreations; by derivation, not by substitution. But these modern materialists, while they are evolutionists in geology (they indeed will hear of nothing else), while they may be evolutionists also in social progress, are, strange to say, catastrophists in philosophy. They would raze all previous beliefs, faiths, philosophies, to the ground, and leave not one stone upon another; and then, out of entirely new materials furnished by themselves, they would erect another and entirely different philosophy. They reverse the old dogma, "Whatever *is*, is right," and make it, "Whatever *is*, is wrong."

The great bar to the speedy establishment of a rational philosophy is dogmatism, self-opinion, self-conceit. The rarest of all gifts is a truly tolerant and rational spirit. In all your gettings, gentlemen, be sure you get this, for *it* alone is true wisdom. But do not imagine, however, that all the dogmatism is on one side, and that the theological. Many, indeed, seem to think that theology has a *preëmption-right* to dogmatism. If so, then modern science has "*jumped the claim.*" Dogmatism has its roots deep in the human heart. It is born of narrowness and pride. It showed itself first in the domain of theology, only because *there* was the seat of power. In modern times, therefore, it has gone to the side of science, because here now is the seat of power and fashion. There are, then, *two dogmatisms*, both equally opposed to the true rational spirit, viz., the old theological and the new scientific. The old clings fondly to old things, only because they are old; the new grasps eagerly after new things, only because they are new. True wisdom and true philosophy, on the contrary, "tries all things," both old and new, "and holds fast only to that which is good and true." The new dogmatism taunts the old for credulity and superstition; the old reproaches the new for levity and skepticism. But true wisdom and philosophy perceives that they are both equally credulous and equally skeptical. The old is credulous of old ideas and skeptical of new; the new is skeptical of old ideas and credulous of new; both deserve the unsparing rebuke of all right-minded men. The appropriate rebuke for the old dogmatism has been put in the form of a bitter sneer in the mouth of Job: "No doubt *ye* are the men, and wisdom shall *die* with you." The appropriate rebuke for the new dogmatism, though not put into the mouth of any ancient prophet, ought to be uttered.

SKETCH OF PROFESSOR EDWARD S. MORSE.

PROF. MORSE was born in Portland, Maine, in 1838. He had an early love of natural history, and at thirteen years of age he commenced a collection of shells and minerals. At the outset he made a specialty of shells, and in 1857 gave his first contribution to the Boston Society of Natural History. He attended school in Bethel, Maine, and while following the usual course of an academy took but little interest in the classics, but busied himself with the woods and streams, and during this time added many new and minute species of land-shells to science.

For several years he followed the profession of mechanical draughtsman in the locomotive-works in Portland; and he also drew on wood for a while in Boston, thus cultivating that remarkable gift of graphic illustration which has since been of such great use to him both in his scientific work and in his public lectures. In 1852 Mr. Morse became a special student of Prof. Agassiz, at the Museum of Comparative Zoölogy at Cambridge, where he remained until 1862, pursuing closely his biological work, but also attending the lectures of Wyman, Cook, and Lowell. While with Agassiz he became more especially interested in the study of the *Brachiopoda*, a class of salt-water bivalve creatures long regarded as mollusks, and of great interest in every aspect; for, although of a low animal type, no other class exhibits such an extensive range in time, geographical distribution, and depth of water. Prof. Morse's first paper on this subject was published in the "Proceedings of the Boston Society of Natural History, 1862." In 1866 he removed to Salem, Massachusetts, where he still resides. Here he became one of the founders of the *American Naturalist*. In 1868 he was elected a Fellow of the American Academy of Arts and Sciences, and in 1871 he received the honorary title of Doctor of Philosophy from Bowdoin College, in which institution he was Professor of Zoölogy and Comparative Anatomy for three years. In 1874 he was elected to one of the university lectureships at Harvard. In 1876 he became a Fellow of the National Academy of Sciences, and the same year was elected Vice-President of the American Association for the Advancement of Science. In the prosecution of his zoölogical investigations Prof. Morse has made many excursions, visiting the Bay of Fundy several times, and also the Gulf of St. Lawrence, and Beaufort Harbor, North Carolina. Desirous of pushing his observations into regions but little examined, Prof. Morse last year went to Japan, for the purpose of dredging on the coast and searching for new specimens in his favorite lines of research. But the heathen of that remote region had the sagacity to detect the character of their visitor, and quickly secured his services, and set

him at work. They said to him in effect, "We do not want the religion, nor the morality, nor the politics of your people, but we want your science." Prof. Morse was accordingly induced to accept the chair of zoölogy in the Imperial University of Tokio. He established a zoölogical station at the Bay of Yeddo, and made large collections for the museum at Tokio, besides a great number of specimens for exchange with American societies. He also discovered the traces of early man in Japan, found a large quantity of ancient pottery, and, in an address before the Asiatic Society at Tokio, he communicated the results of these researches.

Prof. Morse's most important contributions to science have been his investigations on the *Brachiopoda*, which he has pursued with indefatigable industry, going deeply into the question of their structure and affinities. By the help of embryological analysis he has thrown new and important light upon their systematic position in the scheme of invertebrate life. He maintains the view that the Brachiopods must be removed from the division of mollusks and classed with the worms. These ideas have been adopted by many leading naturalists both here and in Europe.

Prof. Morse has made all his expeditions for scientific investigation at his own private expense, and, not being a man of wealth, he has been compelled to lecture much during the winter season to get the means of carrying on his researches during the summer. He has given courses of lectures before the Lowell Institute of Boston, the Peabody Institute of Baltimore, and the Cooper Institute of New York, and has also given courses and single lectures in all the principal cities in the Northern and Western States. Of his rare qualities as a popular scientific lecturer, the thoroughness of his information, his vivid, free, and forcible style as a speaker, and his great skill of rapid delineation upon the blackboard, we have previously spoken.

Prof. Morse is a man of irrepressible activity and an inexhaustible flow of spirits, genial and hearty in manners, a fluent and fertile talker, a copious story-teller, a lover of music, and passionately fond of children. He is a patient, assiduous worker, and has contributed largely to the proceedings of scientific societies and to scientific periodicals. The following are among the most important of his publications:

1. "Description of New Species of Helix" (*Helix asteriscus*), (Proceedings of the Boston Society of Natural History, vol. vi., 1857, p. 1).

2. Description of New Species of Helix" (*Helix milium*), (Proceedings of the Boston Society of Natural History, vol. vii., 1859, p. 1).

3. "The Hæmal and Neural Regions of Brachiopoda" (Proceedings of the Boston Society of Natural History, vol. ix., 1862, pp. 3).

4. "On the Normal Position of Cephalopods" (Proceedings of the Portland Society of Natural History, vol. i., 1863).

5. "On the Occurrence of Rare Helices in Ancient Shell-Heaps" (Proceedings of the Portland Society of Natural History, vol. i., 1863).

6. "Synopsis of the Terrestrial and Fluviatile Mollusks of Maine" (published by the Author. 1864, pp. 4).

7. "Observations on the Terrestrial and Fluviatile Mollusks of Maine" (*Journal of the Portland Society of Natural History*, vol. i., 1864, 2 plates, 26 figures, pp. 63, 104 figures).

8. "Description of New Species of Pupadæ" (Annals of the New York Lyceum of Natural History, vol. viii., 1865, pp. 6, 11 figures).

9. "A Classification of Mollusca based on the Principle of Cephalization" (Proceedings of the Essex Institute, Salem, vol. vi., 1865, 1 plate, 27 figures, pp. 19).

10. "Description of a New Species of Cyclocardia" (*C. novanglæa*), (Annual Report of the Peabody Academy of Science, 2 figures, p. 1).

11. "Note on Classification of Pulmonifera" (Proceedings of the Boston Society of Natural History, vol. xii., p. 1, 1869).

12. "On the Early Stages of Brachiopods" (*American Naturalist*, Salem, vol. iii., 7 figures, pp. 2, 1869).

13. "Position of the Brachiopoda in the Animal Kingdom" (*American Naturalist*, Salem, vol. iii., 3 figures, pp. 2, 1870).

14. "The Brachiopoda a Division of Annelida" (*American Journal of Science and Arts*, vol. l., 3 figures, pp. 4, 1870).

15. "A Reply to Mr. Dall's Criticism on the Brachiopoda a Division of Annelida" (*American Journal of Science and Arts*, vol. l., pp. 4, 1870.

16. "On the Early Stages of an Ascidian" (Proceedings of the Boston Society of Natural History, vol. xiv., 1 plate, 6 figures, pp. 7, 1871).

17. "On the Tarsus and Carpus of Birds" (Annals of the New York Lyceum of Natural History, 2 plates, 48 figures, pp. 22, 1871).

18. "On the Land-slides in the Vicinity of Portland, Maine" (Proceedings of the Boston Society of Natural History, vol. xii., 1 map, 3 figures, pp. 10, 1869).

19. "Remarks on the Relations of Anomia" (Proceedings of the Boston Society of Natural History, vol. xiv., 6 figures, pp. 4, 1871).

20. "Remarks on the Adaptive Coloration of Mollusca" (Proceedings of the Boston Society of Natural History, vol. xiv., pp. 5, 1871).

21. "On the Early Stages of Terebratulina" (Memoirs of the Boston Society of Natural History, 2 steel plates, 58 figures, pp. 11, 1871).

22. "On the Oviducts and Embryology of Terebratulina" (*American Journal of Science and Arts*, vol. iv., 17 figures, pp. 3, 1872).

23. "On the Systematic Position of Brachiopoda" (Proceedings of the Boston Society of Natural History, vol. xv., 58 figures, pp. 60, 1873).

24. "Embryology of Terebratulina" (Memoirs of the Boston Society of Natural History, vol. ii., 2 plates, 108 figures, pp. 15, 1874).

25. "Apparatus for illustrating the Variations of Wave-Lengths by the Motion of its Origin" (Proceedings of the American Association for the Advance of Science, vol. xxii., 3 figures, pp. 3, 1874).

26. "Relationships of the Tunicates" (Proceedings of the Boston Society of Natural History, vol. xiv., 1874).

27. "Observations on the Spittle-Insect" (Proceedings of the Boston Society of Natural History, vol. xiv., 1874).

28. "First Book of Zoölogy" (D. Appleton & Co., publishers, 321 figures, pp. 191, 1875. Reprinted in London, and translated into Japanese).

29. "On a Diminutive Form of the Male in Buccinum Undatum" (Proceedings of the Boston Society of Natural History, vol. xviii., 4 figures, pp 3, 1876).

Prof. Morse came back from Japan to give some lectures here the past season, and returned to that country in April with his family, to continue work there a year or two longer.

CORRESPONDENCE.

NIGHT-AIR IN CITIES.

To the Editor of the Popular Science Monthly.

YOUR April correspondent, Mr. C. W. Johnson, in his critique on my brief note which appeared in your pages of February last, either has misapprehended the issue I there made with Dr. Niemeyer's article in reference to the salubrity of night as compared with day air in cities, or he has stumbled upon the unwarrantable conclusion, solely through the bias of his own cerebration, that, because I did not mention, in the short compass of a few lines, all the forms of local urban insalubrity, therefore I do not believe some of them exist.

Having imagined that I had put the issue so plainly that no reader could fail to understand it, I am at a loss to spell it out any clearer for Mr. Johnson. Let me try it in the form of an interrogatory. Is the air in which we live, move, and breathe, more likely to be charged from local sources with pollutions that produce disease when comparatively still and calm, as during the night, during the day, when stronger currents are more apt to prevail? Dr. Niemeyer says that the night-air of cities is purer than the day-air, while I, in the language of Mr. Johnson, "assume to correct" his statement by showing by a fact or two that moving air is less apt to be intensely charged by any focus of corruption than that which is almost motionless and circumjacent to the source of contamination. The issue was made on the point as to the *time* most favorable for the atmosphere to acquire impurities the most largely from local sources of pollution, not as to the nature or *forms* these impurities may assume, or as to whether they are gaseous, granular, molecular, organic, or inorganic.

Yet, upon the putting of the issue thus plainly, Mr. Johnson represents me as believing that "the insalubrity of city air depends upon the amount of non-respirable gases (!) that may be diffused into the respirable ones"—whatever this may mean—"and is wholly independent of the condensible effluvia of the vaporous kind, or of the organic germ-dust that the heat and stir of the day may keep suspended."

In candor I must say that only those whose ideas are crude and vague upon the subject of the atmosphere as a vehicle of contagia or *materies morbi* would pen such a sentence. Does Mr. Johnson suppose that the *contagium vivum* of scarlatina, or of typhoid fever, or of small-pox, is anything like the heavy dust of the streets, or that it needs the stir of day-air to keep it suspended? Does he not know that the contagia of these diseases are so subtilely diffused and attenuated that the highest magnifying power is unable to isolate or detect them? An investigator now and then has imagined that he has discovered the spores of infection, but only one as yet has made a near approach to settled verification.

To relieve the mind of Mr. Johnson as to my benighted condition on the subject of germ-dust, I beg to refer him to the *Philadelphia Medical and Surgical Reporter*, January 13, 1877, in which I take the ground that the theory of a *contagium vivum* is the only tenable one by which to account for the genesis and spread of some infectious diseases. The unlimited self-multiplication of definite forms or special phases of force, as, e. g., in small-pox, scarlatina, etc., is an attribute only of living matter. There is no more likelihood of the spores of scarlatina being converted into those of small-pox than there is of the germ of a dog being converted into that of a horse. All, in common, only reproduce after their kind.

Of course, the hypothetical spores of an infectious disease are not subject to the chemical law of gaseous diffusion; yet, as such contagia show in various ways a high degree of volatility, stillness of the air is obviously far more favorable to their large aggregation in any particular locality than rapid air-movement. Every intelligent physician is well aware that one of the very best methods of preventing the spread of an infection through a house is by good ventilation or running air. But all this is against Niemeyer's notion of the superior salubrity of still night-air, as compared with the rapid air-movements during the day. The day-air mobility is the analogue of house ventilation—the night-air stagnation the analogue of concentrated house impurity.

If Mr. Johnson desires to know, as it is presumable he does from his inquiry, how "noxious effluvia, if they obey the law of the gaseous diffusion of permanent (!) gases, hover over low marshes and putrefying cesspools," he has only to study the law in any elementary treatise on chemistry. If the effluvia be sulphuretted hydrogen, it will diffuse very rapidly; if it be carbonic acid, much more slowly—specific gravity having something to do with the process. But, in either case, the hovering is greatly promoted by the stillness of the atmosphere, as dur-

ing the night. Or, let him place a speck of spoiled egg in one corner of his house: its sulphuretted hydrogen will soon be perceived throughout all the connecting rooms, but the strongest near the speck, unless it be carried out of the house by a current of air. The attenuated diffusion of deleterious gases tends to render them harmless—their concentration to produce disease by a *de novo* process. The inspiration of concentrated or nearly pure sewage-gas has often caused instant death, a larger dilution habitually inspired often breeds fever, but an attenuated amount of it is not appreciably harmful. And what is more promotive of this dilution or attenuation than the great mobility of day-air?

J. R. Black.

EDITOR'S TABLE.

HOW NEW YORK GOT A COLLEGE.

NEW-YORKERS are somewhat exercised over the question what to do with their college, a problem which it ought to be easier to solve, by remembering how they came by it. What on earth New York City wanted with a college, when there were two good ones already in the town, not half full of students, might be a perplexing inquiry, did we not know that corporations, as well as individuals, often find themselves possessed of things which they don't want and never intended to have. The people did not say, "Go to, let us have a college, cost what it will, and teach Columbia and the University how to manage a higher institution of learning." The city has been drawn into running an opposition line to these establishments in a very different way, and the case is instructive as showing that education can be "managed" as well as other public interests.

What the people of New York did propose, upward of thirty years ago, was to organize a sort of polytechnic or practical high-school, connected with the school-system of the city, to give a little extra preparation to boys, who expected to devote themselves to some form of mechanical industry, and not to the learned professions. If we are not mistaken, such was the explicit object of the institution, and it was so stated upon the ballots by which the citizens voted to establish such a school. This was done by a very large popular majority, and it was set agoing under the name of the "Free Academy." But the movement was premature for New York, or its direction fell into incompetent hands, as nothing efficient was done to stamp it with the character it was designed to have, or to carry out intelligently its distinctive purpose. The plan of education wanted had to be theoretically shaped, and should have been then cautiously carried into practice, by the selection of a faculty in thorough sympathy with the idea, and as well qualified for the work as could anywhere be found. But the parties chosen failed in these respects. That they were unfit to be intrusted with the responsibility, was shown by their work, and by the fact that they were dissatisfied with the status of the concern, and wanted it turned into a "regular college." They complained that their graduates did not stand well at a distance from home, as a "Free Academy" was regarded as not amounting to much. They accordingly set to work to change it, and, by quiet, persistent effort, they at length lobbied a bill through the Legislature at Albany, abolishing the "Free Academy," and creating in its place "The College of the City of New York." How completely the original purpose of the institution was abandoned in this transformation, and the old idea of a classical college substituted, was well shown by the official and authoritative address of Judge Larremore, President of the Board of Education that voted the supplies, and also President of the Board

of Trustees of the new college. He proclaimed that the "Free Academy" was dead, that he knew nothing of it, and curtly brushed aside as no longer of interest the objects for which it was founded, and the policy by which they were to be secured. He went back and expatiated on the mediæval origin and classical ideal of colleges and universities, defended the scholastic conception of culture in contrast with modern innovations, eulogized Latin and Greek, and went in for old-fogyism generally. How entirely the spirit of the original undertaking was ignored and disavowed was well illustrated by the fact that when somebody quoted, in behalf of modern scientific culture, an authority whose work upon education has been translated into a dozen languages, and has exerted an immense influence in modifying plans of study, Judge Larremore contemptuously dismissed the matter, by saying that the authority was of no weight, as the author of the book had never been through college, and was nothing but a railroad engineer. Even a railroad engineer might have counted for something, on the theory by which the "Free Academy" was established; but in the policy of the new classical institution this sort of men seemed to get but little consideration.

And thus it came about that New York finds itself the proprietor of a "regular college." The people proposed to have a high-school, free for poor boys who had attended its common schools, to get some adequate preparation for industrial avocations, and which it was supposed could be carried on for $20,000 a year; and they now find themselves cheated out of their intentions, and saddled with an ordinary college, costing $150,000 a year, more or less. Of course, the repudiation of the original school, and of the ideas which led to its establishment, was not submitted to a popular vote, and it is equally certain that, if the projected change had been thus submitted, it would have been overwhelmingly rejected. And yet, by all the reasons at present urged for the continuance of the college, the people would have been in duty bound to establish it. Indeed, the controversy which has been going on in the newspapers of late, as to whether the city of New York shall abolish its college, is chiefly significant as affording a sort of register of public sentiment on the policy of State education. The college has this use, that it forces the extreme issue in regard to the educational functions of government, and it is noteworthy that the contest has elicited strong expressions in favor of committing the whole business of education to the State. Having affirmed the voluntary principle in religion, and denied the right of the State to meddle in this most important concern—having affirmed that the individual is a better judge in this matter than the State can be—when it comes to education, we deny the voluntary principle, deny that individuals here know what is best for themselves, and that the State—that is, the politicians who happen at any time to be in office—is better than the people to be intrusted with the absolute control of the subject. The history of the New York College is merely a sample of the manœuvring by which jobs will be carried, with no reference to the popular will, just in proportion as education is given over to political management.

THE LIBERTY OF SCIENCE AND EDUCATION.

An interesting controversy has sprung up in Germany upon this subject, the most important utterances of which we have had translated and published for the benefit of American readers.[1] A part of the discussion has been made use of in England and in this

[1] *See* the addresses of Profs. Haeckel and Virchow, in the Popular Science Monthly Supplement, No. X., and Hellwald's paper in No. XI.

country in a way that makes some comment desirable.

Prof. Haeckel, of Jena, gave an address last September at Munich, before the "German Association of Naturalists and Physicians," in which he took the ground that the doctrine of evolution should be made a part of the system of general education in that country.

Prof. Virchow replied to Haeckel in a speech before the same body, on the "Liberty of Science in the Modern State," and argued eloquently against the educational project. He said that the freedom of science now enjoyed in Germany is but of recent growth, and may be imperiled if men of science do not exercise moderation. He referred to the fact that the German socialists are Darwinians, and cautioned the *savants* against so lending themselves to the purposes of this dreaded party as to make it necessary for the state to interfere. But Prof. Virchow went further, and maintained that the measure proposed would be unjustifiable, because the theory of evolution is not yet sufficiently proved. He did not reason against it, and is understood to be himself an adherent of the doctrine. But, he said, it is not yet established. As an anthropologist he declared that no progress had been made in that branch of science toward the establishment of the theory of the descent of man from the lower forms of life. He did not object to it, and considered it a desideratum of science that might be realized at any time. But the proof, he affirmed, is wanting, and the burden of his speech was that what *may be*, or is merely *probable*, must not be taken as fact, or made use of in education.

It is not to be supposed that so authoritative a statement would be neglected by those who are troubled about the adventurous spirit of modern science. Ever since his Belfast Address there have been ominous whispers that the next number of the *Quarterly Review* would contain an annihilating attack upon Prof. Tyndall; and those interested in this serious result have waited curiously for the onslaught, until they began to fear that the editors had backed out. But the German professor has come to their rescue, and in the January issue they let fly their shaft, barbed with Virchow's address. Nor are the Americans behind the English in utilizing the authority of the Berlin physiologist. Prof. Gray, of Cambridge, introduces the main parts of Virchow's argument to the pages of the New York *Independent*, with comments designed to enforce its special lessons. He prizes the address as "a timely and earnest protest against what may be called *platform science*—not peculiar to Germany, nor to advanced evolutionists—against that form of scientific dogmatism which propounds unverified and unverifiable speculations as the conclusions of science." Now, we must think that Prof. Gray has here failed to make the most telling use of his opportunity. Dogmatism and undue license of speculation are undoubtedly bad things, to be always condemned, and nothing certainly could be more proper than for Prof. Gray to warn the readers of the *Independent* against indulgence in those easily-besetting sins. But would not the point have come out a little better if Prof. Gray had said something like this: "Dogmatism—that is, arrogance of opinion, and the disposition to pronounce confidently upon matters that are incapable of being known or verified—is a universal mental habit, inveterate in proportion to people's ignorance, against which education makes but slow headway, which has ever characterized theology, and is most fostered by those powerful agencies in society—churches, Sunday-schools, and religious newspapers? All of these agencies enforce the early and passive acceptance of dogmas that are beyond the sphere of verification, and teach that repose of belief is the great end to be sought, and doubt a heinous thing not to be

tolerated upon pain of eternal retribution. Science, on the contrary, begins with questioning, and, by insisting upon evidence, has restricted the sphere of speculation, and made belief more a matter of reason, and in this way it has done much to destroy the dogmatic spirit. Yet this tendency to dogmatism is so deep and strong in human nature, as at present trained, that even scientific men often yield to it, and put their baseless speculations in place of science, and here is a German *savant* of great authority who says so." This is probably what Prof. Gray meant if he had explained himself more fully, for surely one cannot suppose he intended to encourage the bad habits of one class by telling them how bad are those of another.

Let us now glance for a moment at Virchow's test of what ought to go into the schools. Prof. Gray quotes the following passage: "From the moment when we had become convinced that the evolution theory was a perfectly established doctrine — so certain that we could pledge our oath to it—from that moment we could not dare to feel any scruple about introducing it into our actual life, and not only communicating it to every educated man, but imparting it to every child, . . . and basing upon it our whole system of education." To this the reply is, first, that the standard taken is impracticable, and, if adopted, would abolish education altogether; and, second, if it is lowered, as it must be, evolution cannot be kept out of the schools.

It is important to remember here that Virchow is an evolutionist—not, perhaps, an "advanced" evolutionist, but, as Prof. Gray recognizes, a "pronounced evolutionist," like himself, we suppose. And, if so, it must be because there is a certain amount of truth in the doctrine. But, for the purpose here contemplated, the question is not whether evolution is completely proved—it is simply whether there is sufficient truth and value in it to make its introduction into the schools an improvement upon their existing practice. Now, if evolution is true at all, as admitted by Virchow and Gray, and by the leading thinkers of the time, it must, by the very nature of the idea, be a verity in regard to the great method of things around us—how they come, and how they go, and how they are related to each other in the genetical order. Evolution must embody a truth to this extent, from the very necessity of the case, or it contains no truth at all. It is, by its definition, an unfolding in the course of Nature. That there are numerous imperfections in it, matters nothing, for no science is perfect. Astronomy, based upon physics and mathematics, has ranked as the most perfect of the sciences; but, if any one wishes to understand how imperfect it really is, let him read Prof. Newcomb's new book upon the subject. Chemistry is in a state of revolution, and physics is full of unsettled theories. What, in fact, is science but imperfect sciences getting rid of their errors and limitations?

As to evolution, it is enough that it is a mental view which answers to a great reality. Whether it is to be recognized, is not an open question; it is already in the field as a power that is modifying almost every branch of knowledge. It is guiding investigations in the pathway of successful research; it is the broadest principle of unification in Nature that the human mind has yet reached. Can so comprehensive and all-harmonizing a truth be without value as a means of mental culture? Whether Haeckel was wise or not in demanding its formal introduction into the schools, it is certain that the powers which control the German Empire cannot keep it out of the schools. Nothing would be more futile than to demand the teaching of the development theory in the schools of this country, except, perhaps, the

attempt to prevent it. Already it is taught in the text-books of geology, and it will be more and more seen in the manuals of zoölogy, botany, psychology, philology, and history, when these are revised, and adapted to the advanced condition of knowledge.

With such tendencies predominant, how grotesque is the spectacle of a man like Virchow planting himself at the doors of the German schools, and flourishing his test of what is to be admitted there! As the scientific men approach with their subjects, they are stopped by the question, "Can you make oath, gentlemen, to the truth of what you offer?" And so we have a scientific man ruling out science from the schools by a standard not recognized in education, and which, if rigidly applied, would shut up every schoolhouse in Germany. For what would become of history, philology, geography, political economy, and the whole round of studies that are already pursued, if this swearing-test were to be applied to them? The question, as we have said, is whether something can be got that is better than what now exists, as this is the way all progress is secured. In an address of great power, by Prof. Du Bois-Reymond, of Berlin, on "Science and Civilization" (which we shall soon have the pleasure of publishing), the professor says of the religious instruction given in the German schools: "In the semi-official plan of studies, more than half a page of fine print is expended in setting forth the subject-matter of this instruction, while five lines suffice to dispatch the mathematical programme! On reading this half-page, and the corresponding half-page for the upper second class, one imagines he has before him the programme of a theological seminary." So there is a body of dogmatic divinity already in the schools, including, of course, a cosmogony, or theory of creation, and traditional hypotheses without number. To all this Prof. Virchow does not dream of applying his test; but, when the representatives of modern knowledge demand that the teaching shall better reflect the existing state of thought, the admonition comes: "No dogmatism! Winnow your work, gentlemen—nothing but facts are to be admitted here, with their certainties, up to the swearing-point."

Considered educationally, what else is this but the old, exploded policy of pouring facts into mental pitchers? What are facts good for if not interpreted, and what is science without explanation—that is, theory? Would Prof. Virchow swear the atomic theory out of chemistry, and the wave theory out of optics, and the nebular theory out of astronomy; and what would become of his own science of physiology if nothing could be taught of it but what he can make oath to? The highest object of education is to rouse mental activity, to set pupils to thinking, to encourage them to make their own observations and their own independent reflections; and this can in no way be done so effectually as by linking educational methods to the great movements of thought that are absorbing the world's attention, outside of the schools. To deal only in culture with demonstrated facts, and thus to reduce the process to one of bare acquisition, is a deadening and paralyzing process, not suited to prepare students to use their minds to the best advantage in the conduct of practical life.

Nothing can be clearer than that the liberty of science and the liberty of education, the progress of science and the progress of education, are indissolubly linked together. Whewell has shown us how, in the development of the human intellect, the great steps of culture have followed and resulted from the great steps of discovery that have successively enlarged the sphere of human knowledge. And it was not because certain new facts were poured in at each epoch of discovery, but because new ideas, new methods, new modes of

mental activity, were introduced. These are invaluable in education, and if shorn away, so that nothing but direct results are imparted, the quickening, arousing influence of science is lost to culture. Karl Grün well observes: "Science either enjoys perfect liberty, or she is not free at all. Setting up hypotheses and tracing their ultimate consequences are part and parcel of science, and of the liberty of science;" and we may add that its use in this form is a part of the liberty of education.

It is one of the chief glories of science that it has first taught men the supreme value of truth, and the disciplines of character that the earnest pursuit of truth involves. Truth on its own account and for its own sake is its one great object, and, in proportion as it can be incorporated in education and made the incentive of mental activity, will education attain its highest and noblest object. A writer in the German periodical *Kosmos*, replying to Prof. Virchow, thus gives effective expression to this idea:

"Scientific research aims at the discovery of truth, never inquiring who is to be benefited thereby. The question, *Cui prodest?* (Who is benefited?) is fortunately of as little account in science as the other question, *Cui nocet?* (Who is hurt?) Hence whether the evolution doctrine favors the Socialists or the Ultramontanes, the high and dry Conservatives, the Moderates, the Liberals, the Radicals, or any other party, must be a matter of *entire indifference* to the earnest investigator, and must not be permitted for a moment to lead him astray in his researches. *The truth must be established for its own sake*, and for no other purpose. Any other consideration, even though it were urged by a Virchow, must be absolutely rejected. Ever since science first began there have been heard authoritative voices calling 'Halt!' to the restless spirit of speculation, and it were a grave injustice not to recognize the value of such admonitions. They who warn against danger, and they who engage in scientific speculation, are both indispensable for the development of science; but we must ever bear in mind that scientific progress always, almost without an exception, has come from the labors of those who dared to give expression to thoughts which were as a leaven to the minds of their contemporaries, and who were persecuted for heresy, and laid under a ban by the authorities. The most splendid triumphs of science are the fruit of the empiric demonstration of ingenious hypotheses. Even in cases where these hypotheses have proved untenable they have *caused men to think*, and that in itself constitutes a new advance of science. We could as little dispense with them as with the leaven in bread. All honor, then, first of all to the men to whom we are indebted for hypotheses which have given a stimulus to research; which, so to speak, constitute a landmark in the history of science; finally, in the *mastering* of which, in one sense or the other, a full generation or more has been employed! Honor, again, to those intellectual princes of whom the German proverb is true that, 'when kings build, there is work for cartmen!'"

PROFESSOR MAX MÜLLER ON "THE ORIGIN OF REASON."

And, while we happen to be on the subject of evolution in Germany, we may refer to another episode in relation to this subject. Prof. Max Müller, well known as a philologist, has written an ambitious paper on "The Origin of Reason," in which he follows Prof. Ludwig Noiré, a German philologist, and called a "rank evolutionist." Müller points out how Prof. Noiré has laid under contribution Spinoza, Descartes, Leibnitz, Kant, Locke, Schopenhauer, and Geiger, for materials to construct an evolution theory, his own contribution being that the development of mind is to be come at through the study of language. Noiré does not think much of Darwin, but prefers Cuvier, and works up his scheme out of metaphysical materials, rather than the results of modern science. This Müller indorses, saying, "Every system of philosophy which plunges into the mysteries of Nature without having solved the mysteries of the mind, the systems of natural evolution not excepted, is pre-Cartesian and mediæval." It is somewhat curious to characterize as mediæval that new spirit which arose

and put an end to the mediæval period —the giving precedence to the study of Nature. The truth of the case seems to be that Noiré perceived that evolution has come to be the great basis of philosophy, and therefore accepts it and applies it in the study of the interactions of psychology and language; and yet Max Müller tells us that "Noiré's philosophy rests on a most comprehensive theory of evolution; it is the *first attempt* at tracing the growth of the whole world, not only of matter but of thought also, from the beginning of things to the present day." This is certainly a remarkable claim, and we are at once interested in the intellectual career of the party in whose behalf it is made. It turns out that Noiré's first book, "The World as an Evolution of Spirit," was published in 1874, and the last in 1877. As he subsequently repudiated that first book, the gestation of his system, involving an analysis of the "Growth of the Whole World," took less than three years. Prof. Müller says this was the "first attempt," etc., although he was perfectly aware of the fact that Herbert Spencer is the only man that has ever dealt with the subject comprehensively, and also that he published the complete prospectus of his system fifteen years before Noiré issued his first book. Mr. Spencer, in his last volume, on Sociology, has no doubt seriously damaged Müller's favorite theory of myths; but it would be more creditable to the Oxford professor, either to answer him, or acknowledge the defeat, rather then to vent his resentment by such absurd misrepresentations.

LITERARY NOTICES.

TREATISE ON CHEMISTRY. By H. E. ROSCOE, F. R. S., and C. SCHORLEMMER, F. R. S., Professors of Chemistry in Owens College, Manchester. Vol. I. The Non-Metallic Elements. New York: D. Appleton & Co. Pp. 769. Price, $4.

CHEMISTRY undoubtedly stands among the first of the progressive sciences. Its field is so large, its applications so numerous and practical, and the number of its devotees in all countries so great, as to secure the steady and rapid advance of the science. As a consequence of this, it leaves its literary monuments behind, much as a railway-train leaves the milestones. An exposition of the subject, no matter how completely it may represent its position at a given time, quickly falls behind and becomes antiquated. The large works of Regnault and William Allen Miller, which were standards a few years ago, are now quite out of date; valuable in many respects for reference, they do not embody the results that have been attained since. There was, therefore, need of a new comprehensive treatise on chemistry to take their place in colleges and laboratories. This want has been supplied by the combined labors of Profs. Roscoe and Schorlemmer, the first volume of which is now published. The character of the work they have undertaken is thus stated by its authors: "It has been the aim of the authors, in writing the present treatise, to place before the reader a fairly complete and yet a clear and succinct statement of the facts of modern chemistry, while at the same time entering so far into a discussion of chemical theory as the size of the work and the present transition state of the science permit. Special attention has been paid to the accurate description of the more important processes in technical chemistry, and to the careful representation of the most approved forms of apparatus employed."

The work opens with an excellent historical sketch of the science on the basis of Kopp's history, and this feature is continued in dealing with the most important elements and compounds throughout the book. A marked feature of the work, and one that will be appreciated in the class-room, is the prominent attention that has been given to the representation of apparatus adapted for lecture-room experiment. The numerous new illustrations required for this purpose have all been taken from photographs of apparatus actually in use. The names of the authors are a guarantee of the accuracy and thoroughness of their work, while the proportions in which the various divisions are presented are adapted to the use of students who desire to obtain a thorough general knowledge of the science. The work is

printed in large, clear type, presenting an attractive page, and its illustrations are numerous and of a superior order.

A PRACTICAL TREATISE ON DISEASES OF THE EYE. By ROBERT BRUDENELL CARTER, F. R. C. S. With numerous Illustrations. London: Macmillan & Co. Pp. 591. Price, $4.

THIS work, by one of the most prominent ophthalmic surgeons of London, has been some time published, and has an excellent character with the profession. Attention being increasingly drawn to the impairment of the health of the eye in our schools, and by various kinds of mismanagement, we were anxious to consult some modern authoritative work on the maladies of the eye, and selected this volume for the purpose. Dr. Carter is a philosophical student of his subject, and twenty-five years ago published an interesting volume on the influence of civilization in modifying diseases of the nervous system. But, although he writes as a thinker, the author has made the present work thoroughly practical. It comprises his lectures at St. George's Hospital on common forms of eye-disease which he had occasion to deal with in practice; and it is this circumstance which gives to the treatise its chief merit. It contains many illustrations of the structure of the eye, ophthalmic instruments, and modes of operation.

A HISTORY OF ENGLAND IN THE EIGHTEENTH CENTURY. By WILLIAM EDWARD HARTPOLE LECKY. New York: D. Appleton & Co. Two volumes. Pp. 1,325. Price, $6.

MR. LECKY has won an assured and distinguished place as a philosophical historian. We were among those who had no hesitation in saying that he fully established this character in the publication of his first considerable work, "A History of the Rise and Influence of the Spirit of Rationalism in Europe;" and his claim as an original historical thinker was confirmed by the subsequent appearance of his "History of European Morals." The direction of thought, partially opened by Macaulay, and more vigorously pursued by Buckle, which takes account of the great pacific forces that have been involved in modern civilization, is adopted by Mr. Lecky, and has been followed out by him, systematically and most ably, in his successive treatises. The old and vulgar conception of history as a mere narration and chronicle of incidents, a gossipy delineation of the great personalities that have figured in public affairs, a picture of court manners, a threading-out of diplomatic intrigues, with abundant description of battles, campaigns, wars, conquests, and the overturning of dynasties, Mr. Lecky leaves to those who can be satisfied with it. These are very much surface-effects, well fitted, indeed, to strike the imagination, but of trivial moment in comparison with those profounder agencies by which modern society has been shaped and the real work of civilization carried forward. Science has been at the bottom of a revolution in recent times, which has compelled not only a re-estimate of the importance of subjects to be dealt with in history, but a reversal of former judgments, by which subjects long neglected must henceforth have supreme regard. The influence of scientific habits of thinking has deepened the study of history, antiquated its superficial methods, and carried us down to those deeper and wider causes that have determined the amelioration of humanity. Mr. Lecky takes up the work of the historian avowedly from this point of view, and, in the two solid volumes now before us, he has applied it to an important period of the history of his own country. It is a splendid theme, for England has a central and commanding position in the movement of national development; and the times considered by Mr. Lecky were fruitful of profound changes and the most important results. The purpose and plan of his work are thus indicated in his preface:

"I have not attempted to write the history of the period I have chosen year by year, or to give a detailed account of military events; or of the minor personal and party incidents, which form so large a part of political annals. It has been my object to disengage from the great mass of facts those which relate to the permanent forces of the nation, or which indicate some of the more enduring features of national life. The growth or decline of the monarchy, the aristocracy, and the democracy, of the Church and of Dissent, of the agricultural, the manufacturing, and the commercial interests, the increasing power of Parliament and of the press, the history of political ideas, of art, of manners, and of belief; the changes that have taken place in the social and economical condition of the people,

the influences that have modified national character, the relations of the mother-country to its dependencies, and the causes that have accelerated or retarded the advancement of the latter, form the main subjects of this book."

NATURAL LAW: AN ESSAY IN ETHICS. By EDITH SIMCOX. Boston: Osgood & Co. Pp. 361. Price, $3.50.

THIS is a profound disquisition on the deep things of metaphysical and moral philosophy. The treatment is very didactic, and not altogether inviting; but the author is a radical thinker, and tries hard to get down to first principles. The subject is dealt with under the heads of: I., Natural Law; II., Customary and Positive Law; III., Morality; IV., Religion; V., The Natural History of Altruism; VI., The Natural Sanctions of Morality; VII., Social and Individual Perfection. The best thing in the book is an extract from Jeremy Taylor, stating the difficulties that people have in getting along in this world. The passage will bear reproducing:

"Whoever was to be born at all, was to be born a child, and to do before he could understand and be bred under laws to which he was always bound, but which could not always be exacted; and he was to choose when he could not reason, and had passions most strong when he had his understanding most weak, and was to ride a wild horse without a bridle, and, the more need he had of a curb, the less strength he had to use it; and, this being the case of all the world, what was every man's evil became all men's greater evil, and though alone it was very bad, yet when they came together it was made much worse; like ships in a storm, every one alone hath enough to do to outride it; but when they meet, besides the evils of the storm, they find the intolerable calamity of their mutual concussion, and every ship that is ready to be oppressed with the tempest is a worse tempest to every vessel against which it is violently dashed. So it is in mankind; every man hath evil enough of his own, and it is hard for a man to live soberly, temperately, and religiously; but when he hath parents and children, brothers and sisters, friends and enemies, buyers and sellers, lawyers and physicians, a family and a neighborhood, a king over him or tenants under him, a bishop to rule in matters of government spiritual, and a people to be ruled by him in the affairs of their souls, then it is that every man dashes against another, and one relation requires what another denies; and when one speaks, another will contradict him; and that which is well spoken is sometimes innocently mistaken, and that upon a good cause produces an evil effect. And by these, and ten thousand other concurrent causes, man is made more than most miserable."

A DICTIONARY OF MUSIC AND MUSICIANS. A. D. 1450–1878. By Eminent Writers, English and Foreign. With Illustrations and Woodcuts. Edited by GEORGE GROVE, D. C. L. In Two Volumes. Number of pages in Part I., 128. A to Ballad. New York: Macmillan & Co. Price, $1.25.

MUSICAL dictionaries have hitherto been chiefly occupied in explaining the numerous terms and technicalities which have become so prominent in the art. The present work promises to be of a much more comprehensive character, indeed to be a kind of cyclopædia of music, giving "full and accurate information in regard to the lives of eminent composers, the history of musical instruments, the origin and gradual development of musical forms (such as the symphony and the sonata), the career of great singers, and so on." Such is the object of the work of which the first installment is before us, and which is to contain twelve quarterly parts. It is an enterprise of great labor, but the execution thus far shows that it will be thoroughly done. Its main articles are contributed by eminent authorities on musical subjects, and its minor parts have evidently been prepared with assiduous care, under the editorship of Mr. Grove. The work will of course be best appreciated by those most interested in music, but it will be of value to general readers, both for reference and for study, as furnishing the materials of the history of a great and growing popular art. We might object that the type is rather too small to give most attractiveness to the page, but from the copiousness of the information to be presented this became a necessity, in order to keep the volumes within a reasonable magnitude. The work is, however, printed with great clearness; and the musical passages that are freely interspersed in the text, to illustrate the various topics, come out with admirable distinctness. When the enterprise is completed, we shall have another important reference-book in this age of cyclopedic specialties.

PROTEUS, OR UNITY IN NATURE. By CHARLES BLAND RADCLIFF, M. D. New York: Macmillan & Co. Pp. 214. Price, $2.50.

THE object of this work is to illustrate, in a somewhat full and methodical way, the great principle of oneness in Nature—the law

within law, and the communion in all things. In Part I. the author traces out the law of unity in plants, in the limbs of vertebrate animals, in the appendant organs of invertebrate animals, in the skull and vertebral column, in the relations of plants and animals, and of organic and inorganic forms. In Part II. he advances to dynamical and mental phenomena, and traces the unity of physical forces, of vital and physical motion, and of the phenomena of instinct, memory, imagination, volition, and intelligence, and closes with an exemplification of it in the personal, social, and religious life of man. In his preface, the author states that it has been his object to place himself in opposition to the materialistic spirit of the age.

HISTORY OF OPINIONS ON THE SCRIPTURE DOCTRINE OF RETRIBUTION. By EDWARD BEECHER, D. D. New York: D. Appleton & Co. Pp. 334. Price, $1.25.

THIS is a book, of great theological erudition, on the question of the punishment of human beings after death. The unsettled state of opinion on this subject induced Dr. Beecher to take it up and do something to bring about a better agreement among those who believe in future punishment, but differ as to its duration; and, to those who regard such an inquiry as important, the volume will prove interesting. Dr. Beecher says: "The main interest centres on the question, 'What is the doom of the wicked?' This has fixed the attention of the world upon the import of a single word, *aionios*." It seems strange that the question of the eternal doom of immortal beings should be left so uncertain for mankind as to hang upon the interpretation of a Greek word, so that we must look to the philologists to ascertain what is to be our fate through eternity.

VITAL MAGNETISM: ITS POWER OVER DISEASE. By FREDERICK T. PARSON. New York: Adams, Victor & Co. Pp. 230. Price, $1.25.

BY vital magnetism the author of this book, of course, means animal magnetism, and this term has been applied to a class of obscure and irregular effects exhibited by, or induced in, the nervous system, and also to an art of treating certain diseases. The author of the work claims that this country is very much behind Europe in the cultivation of this branch of the healing art, and his work is offered to supply a want to the medical profession arising from this backwardness of the subject, and to furnish evidence of the extent of its European development. The book has been compiled with excellent judgment, and gives account of a large number of cases, chiefly European, which are full of medical interest. It is due to the author to say that (though a Magnetic Physician) he is more modest than the standard ethics of the profession requires, for he neither parades his own cases, nor does he announce the street and number, or even the city, where he is to be found.

What there is in animal magnetism, or vital magnetism, that deserves attention as a method of treating disease, we cannot pretend to say; but those interested will find this book very suitable, as a presentation of its claims, and the evidences of its utility. There is, probably, something in it, and there may be much in it that the medical profession will yet have to recognize; but we advise the cultivators of the method to get rid of the term *magnetism* as quickly as possible, for it is both fanciful and misleading. The fact is, the thing referred to is not magnetism. It is claimed that there are certain effects produced by movements upon the human body, in certain directions, which effects are reversible by reversing the movements. This very naturally suggests analogies to magnets, which are charged and discharged in similar ways, but it no more proves the body to be a magnet than his method of grinding food proves man to be a grist-mill. The danger of such analogies is, that they are always apt to be carried too far. The author quotes approvingly the words of Dr. Ashburner as follows: "Man is a magnet. He has, like all other magnets, poles and equators. But, being a magnetic machine of very complex structure, his magnetic apparatus is divided into many parts. The brain is the chief magnet, and the trunk and extremities are separate magnets, having intimate relations with the chief source of magnetism. We infer from these facts, what is the truth, that the normal currents take a normal course from the brain to the caudal extremities."

MYTHS AND MARVELS OF ASTRONOMY. By RICHARD A. PROCTOR. New York: G. P. Putnam's Sons. Pp. 363. Price, $4.

THIS volume contains an excellent selection of some of the most readable of Mr. Proctor's popular essays. While not systematic studies in strict science, they contain a great deal of scientific information, and are, moreover, enriched by an erudition of side considerations which come from extensive reading, and the assiduous collection of the historic curiosities of the various subjects treated. The subjects of the present volume are—1. "Astronomy;" 2. "The Religion of the Great Pyramid;" 3. "The Mystery of the Pyramids;" 4. "Swedenborg's Vision of other Worlds;" 5. "Other Worlds and other Universes;" 6. "Suns in Flames;" 7. "The Rings of Saturn;" 8. "Comets as Portents;" 9. "The Lunar Hoax;" 10. "On some Astronomical Paradoxes;" 11. "On some Astronomical Myths;" 12. "The Origin of the Constellation Figures."

THE CREED OF CHRISTENDOM; ITS FOUNDATIONS CONTRASTED WITH ITS SUPERSTRUCTURE. By WILLIAM RATHBONE GREG. With a New Introduction. In Two Volumes. Boston: J. R. Osgood & Co. Pp. 549. Price, $7.

THIS work has been before the public some thirty years, and is now announced as in the fifth edition. It has been extensively read, and ranks among the leading books of modern criticism upon the history and character of the Christian Scriptures. The new introduction, made to the third edition, is dated 1873, and contains 94 pages. It is interesting, as a comprehensive review of the contributions of Colenso, Renan, the author of "Ecce Homo," and Matthew Arnold, to the same general subject, and all made after the original publication of Mr. Greg's book. The main idea of the work is that Christianity has undergone the most profound changes since its first promulgation; and this idea is very impressively reiterated in the closing passages to the author's last introduction, of which the following is a part:

"I have but one word more to say—and that is an expression of unfeigned Amazement—so strong as almost to throw into the shade every other sentiment, and increasing with every year of reflection, and every renewed perusal of the genuine words and life of Jesus—that, out of anything so simple, so beautiful, so just, so loving, and so grand, *could* have grown up or been extracted anything so marvelously unlike its original as the current creeds of Christendom; that so turbid a torrent *could* have flowed from so pure a fountain, and yet persist in claiming that fountain as its source; that any combination of human passion, perversity, and misconception *could* have reared such a superstructure upon such foundations. Out of the teaching of perhaps the most sternly anti-sacerdotal prophet who ever inaugurated a new religion, has been built up (among the Catholics and their imitators here) about the most pretentious and oppressive priesthood that ever weighed down the enterprise and the energy of the human mind. Out of the life and words of a Master, whose every act and accent breathed love and mercy and confiding hope to the whole race of man, has been distilled (among Calvinists and their cognates) a creed of general damnation and of black despair. Christ set at naught 'observances,' and trampled upon those prescribed with a rudeness that bordered on contempt—Christian worship, in its most prevailing form, has been made to *consist* in rites and ceremonies, in sacraments and feasts, and fasts and periodic prayers. Christ preached personal righteousness, with its roots going deep into the inner nature, as the one thing needful—his accredited messengers and professed followers say: No! purity and virtue are filthy rags; salvation is to be purchased only through vicarious merits and 'imputed' holiness," etc.

THE ANEROID BAROMETER: ITS CONSTRUCTION AND USE. New York: D. Van Nostrand. Pp. 106. Price, 50 cents.

IT is generally understood that the aneroid barometer is a little instrument, the size of a watch, which depends for its action upon the changes in form of a thin metallic box, partially exhausted of air. As the pressure of the atmosphere varies, the thin walls of the vacuum-chamber move, and the motion is taken up by a suitable mechanism and indicated by a hand on a dial-plate. Captain Fawcett, who has had much experience with the instrument, says the value of the aneroid, as a handy and portable instrument for rapidly obtaining relative heights in surveys, has been underrated. The point chiefly valuable in an aneroid is its portability, as in the pocket it takes up no more room than a watch. Its calculations can be done quickly, and its indications may be generally relied upon within ten or twenty feet. In traveling and making geographical observations, especially in hilly or mountainous regions, it is extremely

convenient. Van Nostrand's little pocket-book gives all the information necessary to make the best use of the aneroid barometer, and it contains copious tables to facilitate calculations.

THE PRINCETON REVIEW, March. Pp. 398. 37 Park Row, New York. Price, 35 cts.

HAVING floated down the tranquil stream of time for fifty-four years, this stanch old orthodox review begins to find that the waters are growing rough, and that the navigation must be closely attended to. So the first thing is to move out of Jersey, and plant itself down in the metropolis, and respectfully announce that it "is not the organ of any theological seminary." It has altered its backing, and it is now understood that instead of a theological establishment it has a big heap of money behind it. This is made probable by such a swelling out of its proportions as would not be justified by any considerations of legitimate business. It will be issued six times a year, at a subscription of two dollars, and, if each number is to contain as much reading-matter as the one before us, it will be dirt cheap, though we are afraid the proprietors will have to draw on their pile to hire their subscribers to read it. This we say entirely with reference to the unconceivable bulk of matter furnished. It seems to be forgotten life is short, and that people generally have much else to do besides reading. However, the scope of the review is broad, as it is to consist entirely of original articles on theology, philosophy, politics, science, literature, and art, and, if it had a good serial novel in it, we do not see why it might not claim to answer all the wants of the reading public. A glance at the articles of the present number shows that they are solid, if not brilliant, while the names Chadbourne, Hodge, Hopkins, Hall, Spear, Atwater, Bowen, West, Alexander, Bishop Cox, Hickok, and McCosh, all of whom have articles in this March issue, are a guarantee that the periodical will maintain its character for theological conservatism.

CREED AND DEED. A Series of Discourses. By FELIX ADLER, Ph. D. New York: G. P. Putnam's Sons. Pp. 243. Price, $1.50.

THE author of this work combines the erudition of the scholar with the independence of the radical thinker. The topics he deals with in this volume are religious and ethical in their character, and the essays are keen in criticism and of marked literary merit. Our readers have had an illustration of these qualities, as the essay in the volume on "The Evolution of Hebrew Religion" first appeared in the pages of THE POPULAR SCIENCE MONTHLY. The papers were delivered as lectures before the Society for Ethical Culture and are published by request of those who listened to them.

TABLES FOR THE DETERMINATION OF MINERALS. By PERSIFOR FRAZER, Jr. Philadelphia: Lippincott. Pp. 119. Price, $2.

PROF. FRAZER adopts, as the basis of his work, the tables prepared by Weisbach, which he has enlarged and completed. The work provides for the student a method of determining minerals from an examination of those physical properties which may be ascertained by the aid of the simplest instruments. In the author's plan, all minerals are divided into three classes: those having a metallic lustre; those of non-metallic lustre, but giving a colored streak; and those of non-metallic lustre, with colorless streak. The tables correspond to this threefold classification, and by a reference to them most minerals can be determined without difficulty. In short, the student has only first to ascertain to which of the three great classes a specimen belongs. He then ascertains first the character of the lustre—if any it has—then its color, the color of the streak, the relative hardness and tenacity, the crystal system, and the cleavage. A glance at the tables will give him the name of the mineral in which all these characters exist in the proportions found in his specimen.

MOUND-MAKING ANTS OF THE ALLEGHANIES. By the Rev. HENRY C. McCOOK. With Plates. Philadelphia: J. A. BLACK, 1334 Chestnut Street. Pp. 43. Price, 75 cents.

WE have had frequent occasion to recount the ingenious researches of Mr. McCook into the life-histories of insects. The present essay is the most voluminous one we have ever seen from his pen, and perhaps also the most interesting. The subject is the wood or fallow ant (*Formica rufa*), whose

hills are familiar to all visitors among the mountains of Pennsylvania. These hills are cones of more or less regularity, commonly of ten or twelve feet in circumference at the base, and from two and a half to three feet in height, though in some instances they have dimensions twice or thrice as great. The author has studied the principles of architecture which guide this ant in the construction of its mounds; also its system of engineering, whereby it overcomes natural obstacles in the construction of its works. Further, he has observed in these ants a curious mode of feeding—a troop of foragers going out, and coming back with abdomens swollen with honey-dew, which they give up to the workers on their return to the mound. The whole memoir gives evidence of very patient and conscientious research.

MECHANICS OF VENTILATION. By G. W. RAFTER, C. E. New York: Van Nostrand. Pp. 96. Price, 50 cents.

MR. RAFTER lays no claim to originality of ideas in this little treatise, his object being rather to reduce to systematic form the existing fund of knowledge with respect to the important problem of warming and ventilation. His essay is in every way worthy of the attention of civil engineers and architects.

ENGINEERING CONSTRUCTION. By J. E. SHIELDS, C. E. New York: Van Nostrand. Pp. 138. Price, $1.50.

THE four general heads under which the author of this work distributes his subject-matter are: "Foundations," "Masonry," "Tunnels," and "Engineering Geodesy." His aim is to expound the true principles of construction, as ascertained by the highest authorities in that branch of science; but no theory, he assures us, is here set forth which has not received confirmation from practical test.

FOUNDATIONS. By JULES GAUDARD. Translated from the French by Vernon Harcourt. New York: D. Van Nostrand. Pp. 104. Price, 50 cents.

THIS is another valuable monograph of Van Nostrand's "Science Series." It is a study in the art of civil engineering, and gives a compendious account of the construction of foundation-works for bridges, piers, viaducts, and all buildings where the weight of the superstructure is so great that the question of foundations is fundamental.

PUBLICATIONS RECEIVED.

The Epoch of the Mammoth. By J. C. Southall. Philadelphia: Lippincott. Pp. 445. $2.50.

Chemical Experimentation. By S. P. Sadtler. Louisville: Morton. Pp. 225.

Browne's Phonographic Monthly. Vol. II. New York: D. L. Scott-Browne. $1 per year.

The House Sparrow. By T. G. Gentry. Philadelphia: Claxton, Remsen & Haffelfinger. Pp. 129. $2.

Putnam's Library Companion. Vol. I. New York: Putnams. Pp. 90. 50 cents.

The Kirografik Teecher. By J. B. Smith. Amherst, Mass.: J. B. & E. G. Smith. Pp. 99.

Mineralogy. By J. H. Collins. New York: Putnams. Pp. 206. $1.50.

Matter and Motion. By J. C. Maxwell. New York: Van Nostrand. Pp. 224. 50 cents.

Planetary Meteorology. By R. Mansill. New York: American News Company. Pp. 60. 50 cents.

Report of the Director of the Central Park Menagerie (1877). Pp. 50.

The Metric System of Weights and Measures. By P. Frazer, Jr. Reprint from the *Polytechnic Review*. Pp. 24.

Adamites and Preadamites. By A. Winchell. Syracuse, N. Y.: Roberts. Pp. 59. 15 cents.

Foul Air and Consumption. By Dr. R. B. Davy. Cincinnati: Reprint from the *Lancet and Observer*. Pp. 12.

Life Insurance, and how to find out what a Company owes You. By G. W. Smith. New York: Van Nostrand. Pp. 28. 25 cents.

The Forces of Nature (illustrated). By A. Guillemin. Parts 2, 3, 4, 5. New York: Macmillan. 40 cents each.

Intercultural Tillage. By Dr. E. L. Sturtevant. From the Report of the Connecticut State Board of Agriculture. Pp. 42.

Report of the Cincinnati Zoölogical Society (1877). Cincinnati *Times* print. Pp. 40.

Meteorological Method. Pp. 15.—Causes of the Huron Disaster. Pp. 4. By William Blasius. Philadelphia: The Author.

Our Public School System. By C. W. Bardeen. Pp. 32.

Ventilation. By Dr. W. C. Van Bibber. Annapolis Md.: Colton print. Pp. 36.

Economic Tree-Planting. By B. G. Northrop. From Report of Connecticut Board of Agriculture. Pp. 29.

European and American Climatic Resorts. By Dr. G. E. Walton. Pp. 12.

Report of the Connecticut Agricultural Experiment Station (1877). New Haven: Tuttle, Morehouse & Taylor print. Pp. 104.

The New Rocky Mountain Tourist (illustrated). By J. G. Pangborn. Chicago: Knight & Leonard. Pp. 64.

Primitive Property. By E. de Laveleye. New York: Macmillan. Pp. 356. $4.50.

Star-Gazing, Past and Present. By J. N. Lockyer (with Plates). Same publisher. Pp. 496. $7.50.

Proceedings of the American Chemical Society. Vol. I., No. 5. New York: Baker & Godwin print. Pp. 104.

The Sugar-Beet in North Carolina. By A. Ledoux. Raleigh: *Farmer and Mechanic* print. Pp. 50.

The Salt-eating Habit. By R. T. Coburn. Dansville, N. Y.: Austin, Jackson & Co. print. Pp. 29.

The Star-Finder, or Planisphere, with Movable Horizon. New York: Van Nostrand.

POPULAR MISCELLANY.

The Growth of Photography.—At one of the public lectures recently given under the auspices of the New York Academy of Sciences, Prof. Charles F. Chandler sketched the progress of photography during the last hundred years. The first authentic record of pictures made by solar agency he finds in Cooper's "Rational Recreations," published in 1774, where an account is given of the marking of bottles by silver salts. Next came Scheele's experiments on the effect of exposing to light paper sensitized by the same salts. The first genuine sun-pictures were probably produced by Bolton and Watt, who were followed by Humphry Davy and Wedgwood. Still, down to the beginning of the second quarter of the nineteenth century, photography had not advanced beyond the stage of producing images of plant-leaves laid on sensitized paper, and exposed to light. These images, crude as they were, soon disappeared on continued exposure of the paper to the light, for as yet no means of fixing the photograph image had been discovered. Niepcé studied the subject experimentally for nearly fifteen years, without any very encouraging results, but in 1824 he associated with himself Daguerre, who in 1839 announced to the world his discovery of a method of producing permanent sun-pictures. Dr. Draper, of New York, added sundry important improvements to Daguerre's method. Fox-Talbot produced the first silvered-paper photograph, which was the germ of the modern sun-picture. The great development came in 1841, when Schönbein discovered gun-cotton. Cotton, he found, when exposed to nitric acid, becomes explosive, and soluble in a mixture of alcohol and ether. The discovery of this latter property was the foundation of the common photographic process, where a film of collodion, sensitized by silver iodide, produces the "negative" image, from which thousands of pictures may be struck off. It was stated by Prof. Chandler that Albert, a photographer of Munich, and Edward Bierstadt, of New York, are engaged in perfecting a process for printing photographs in colors.

The Development of Botanical Science.—The progressive development of botanical science is forcibly exhibited by the *Belgique Horticole*, in a numerical statement of the different species of plants named in sundry ancient documents, and now ascertained by botanists. Thus, in the Bible, we are told, about fifty plants are clearly determined, while about as many more are mentioned in more general terms. Hippocrates mentions 234 species, Theophrastus about 500, Dioscorides over 600, and Pliny 800. In the sixteenth century Conrad Gerner names 800, Charles de l'Escluse 1,400, Dalechamps 2,731, and Gaspard Bauhin 6,000. In 1694 Tournefort describes 10,146 species. He was the first to class the species of plants into genera, of which he reckoned 694. In the eighteenth century Linné defined 7,294 plants, distributed in 1,239 genera. In 1805 Persoon's "Synopsis Plantarum" included nearly 26,000 species, and in P. de Candolle's "Elementary Theory of Botany" 30,000 species are said to be known scientifically. Stendel's "Nomenclator Botanicus" (published in 1824) contains 78,000 names of plants. Loudon's "Hortus Britannicus" (1839) enumerates 31,731 species in 3,732 genera. According to Endlicher (1840), there were 6,895 known genera in the vegetal kingdom, which number is increased to 8,931 by Lindley in the year 1853. In 1863 Bentley estimated the known species at 125,000. The *Belgique Horticole* thus classes the species now known:

60,000 dicotyledons,
20,000 monocotyledons,
40,000 cryptogams,

or, in all, about 120,000 species distributed among 8,000 genera. The species actually cultivated number 40,000, and these are true botanical species, not simply races or varieties.

Facts about the So-called "Rain-Tree."—For some months there has been circulating in the newspapers a notice of a tree

found in Northern Peru, the "rain-tree of Moyobamba," from the trunk of which, as the story runs, "water may frequently be seen to ooze, falling in rain from the branches in such quantity that the ground beneath is converted into a perfect swamp." The facts with regard to this "rain-tree" are stated as follows by Mr. Spence, the traveler, in a letter to Mr. Thiselton Dyer, which the latter has communicated to *Nature*. The tree is not a myth, but a fact, though the current story is not quite exact. Mr. Spence first witnessed the phenomenon in question in September, 1855. On a certain day, about seven o'clock in the morning, while in latitude 6° 30′ south, longitude 76° 20′ west, he found a "lowish, spreading tree, from which, with a perfectly clear sky overhead, a smart rain was falling. A glance upward showed a multitude of cicadas sucking the juices of the tender young branches and leaves, and squirting forth slender streams of limpid fluid." The tree belonged to the acacia tribe, but Mr. Spence was informed by his native attendants that almost any tree, when in a state to afford food to the nearly omnivorous cicada, might become, *pro tempore*, a *Tamia-caspi*, or rain-tree. Afterward, he himself verified this fact more than once. "As to the drip from the tree causing a little bog to form underneath and around it," writes Mr. Spence, "that is a very common circumstance in various parts of the Amazon Valley, in flats and hollows, wherever there is a thin covering of humus, or a non-absorbent subsoil, and the crown of foliage is so dense as to greatly impede evaporation beneath it."

Clearing Land with Dynamite.—A severe storm of wind having blown down a number of large trees on the estates of the Earl of Stamford and Warrington, recourse was had to the use of dynamite for the purpose of breaking up the roots, that being esteemed the most expeditious mode of removing those incumbrances. The first experiment was made on four very large elm-roots. An auger-hole, one and a half inch in diameter was bored in each, and charged with eight dynamite cartridges, which, on being exploded, shivered the roots into fragments suitable for firewood. The second experiment was on two huge oak-roots. These were simply charged by placing a few cartridges of dynamite in natural crevices of the roots, without any auger-hole. The charges were exploded, and the roots blown to pieces of manageable size. Next, an auger-hole was bored in each of seven oak-roots, and charged with two cartridges each, the result being that all were broken up. The fourth experiment was on an extraordinarily large ash-root, the great fangs of which were lying undisturbed in the ground. Underneath this a number of crowbar-holes were made and charged with dynamite. The fuses were all cut the same length and fired simultaneously, blowing the whole mass out of the ground.

Color-Blindness.—In an article on "Defective Vision considered in its Relations to Railroad Management," published in the *Chicago Railway Review*, Mr. Thomas F. Nelson, optician, remarks as follows on the phenomenon of color-blindness: "This defect but rarely assumes the form that would be termed *absolute* color-blindness, or want of *any* sensation of color. Where this form is perfectly developed there is generally a sharp, well-defined appreciation of differences between light and shade, or even between the finest grades of apparent brightness or intensity; but recognition of color is entirely wanting, there being no distinction whatever between different colors having the same degree of intensity. A curious fact might be noticed in this connection, that these defects are but rarely found in women.

"The more common form is that caused by the absence of perception of one of the three fundamental colors. These are mentioned in the order of their comparative frequency, viz., where the elementary sensation corresponding to *red* is wanting; next, the absence or imperfect perception of *green*, and third of *blue*. It will be noticed as a remarkable fact that the first two mentioned are now used to make up the entire code of railway-signals, and that this defect for *red* occurs more frequently than for any other color. This is an item of the greatest importance in railway and vessel management, since *red* is almost always used for the danger-signal. To add still fur-

ther to the deceptive and dangerous character of the defects, I have, in the course of my experiments, found a number of persons who were unable to distinguish between the primary colors at night, while their perception or sensation of color by daylight was apparently perfect. Again, I have found another anomaly which, until it has been more thoroughly investigated, and the real causes that produce it are understood, I shall designate as a form of color-blindness, although I am in doubt myself as to its dependence upon any of the principles that enter into that defect; this is an inability to distinguish between or to recognize the primary colors at certain distances, varying more or less in individuals. This was found to be the most difficult of all defects to detect in the various cases I have examined, amounting to some nine or ten, in the regular course of my business as optician during the past three years. I have found no two of them at all alike except in general results.

"I have kept records of various accidents that have occurred, both upon land and water, during the past few years, and I have gathered such information about some of them as I could get outside of official sources—often I was unable to get any of any value, but I am convinced beyond a doubt that a large proportion of them could have been traced to this defect for a correct solution as to the primary causes of the accident. The query has been made, that if these defects in their various forms are as numerous and of such a dangerous character as has been shown, how can we account for such a comparatively small number of accidents occurring which might be charged to them? I have attributed it to the high average intelligence and acquired cautiousness of engineers and pilots as a class. They have become so accustomed to be on the lookout for danger that their suspicions are easily aroused, which creates a sort of instinct that governs their actions, and they do not recognize but that their perceptions are correct."

Sewer-building.—The general principles of sewer-building are, says the *Polytechnic Journal*, that each day's influx should be promptly passed out by natural flow or flushing, and not allowed to deposit sediment. The alignment should be good, especially at the bottom; the descent should be uniform, and the interior surface smooth, so as to reduce friction and not to cause clogging; the walls should be absolutely impervious, and the suction such as will cause the most rapid possible flow, with a minimum of sewage. Rapid flow being essential, smooth interior walls should be provided; mortar projecting from the joints of a brick sewer markedly impedes the flow and arrests putrefiable matter. A flat-bottomed sewer is the worst form as regards the velocity of the flow; a circular bottom is better; an egged-shaped section, with the point downward, permits of a minimum current flushing and cleansing the bottom. In brick sewers the mortar, constantly moist, must sooner of later succumb to the disintegrating action of the matters passed through it, and the whole line gradually passes into the condition of a sieve, allowing the liquid portions of the sewage to pass through it and to saturate the subsoil, but retaining the solids. From the consequent saturation of the soil result contagious fevers. Hence vitrified clay pipes are now almost universally employed. The "slip" glazing applied to these pipes resists the severest chemical action of sewage-water. The "slip" glaze is produced by dipping the unbaked clay into a mixture of "slip-clay" or Albany-earth and water, which, under a white heat continued from twelve to thirty hours, produces a vitreous and very durable silicious surface upon the wares.

Remarkable Land-Slides.—Bear-Tooth Mountain is one of the most prominent landmarks in Northern Montana; it is plainly visible from Helena, thirty miles distant. It presents, or rather used to present, the appearance of two great tusks rising hundreds of feet above the general contour of the mountains. One of these tusks, the smaller one, which was fully five hundred feet high, three hundred feet in circumference at the base, and one hundred and fifty feet at the top, was recently dislodged from its place and precipitated into the valley below. A few weeks since, according to the Helena *Independent*, a party of hunters chasing game several miles north of the Bear Tooth

heard a rumbling sound and felt a quaking of the earth, which they took to be a veritable earthquake. But, as the sound was not repeated, they soon forgot the occurrence, and continued their chase till they came to the vicinity of the Bear Tooth. What was their surprise to find that the stupendous mass of the eastern tusk had been dislodged, sweeping for a quarter of a mile through a forest of heavy timber, and overwhelming with its *débris* the ground round about! Virginia City, in the same State, is gradually slipping down the mountain-side on which it is built. The movement is gradual, and imperceptible at the surface. A water-main recently uncovered was found telescoped for the space of one foot, and otherwise injured. A fissure has been traced in the ground on the western side of the town; on one side of this the ground is three feet higher than on the other.

The Death of a Generation.—A writer in an English magazine studies from birth to death the march of an English generation through life, basing his remarks on the annual report of the registrar-general. The author singles out, in imagination, a generation of one million souls, and finds that of these more than one-fourth die before they reach five years of age. During the next five years the deaths number less than one-seventh of those in the first quinquennium. From ten to fifteen, the average mortality is lower than at any other period. From fifteen to twenty the number of deaths increases again, especially among women. At this period, the influence of dangerous occupations begins to be seen in the death-rate. Fully eight times as many men as women die violent deaths. The number of such deaths continues to rise from twenty to twenty-five, and keeps high for at least twenty years. Consumption is prevalent and fatal from twenty to forty-five, and is responsible for nearly half the deaths. From thirty-five to forty-five the effects of wear and tear begin to appear, and many persons succumb to diseases of the important internal organs. By fifty-five the imagined million has dwindled down to less than one-half, or 421,115. After this, the death-rate increases more rapidly. At seventy-five, there remain 161,124, and at eighty-five, 38,565. Only 202 reach the age of one hundred. At fifty-three, the number of men and women surviving is about equal, but from fifty-five onward the women exceed the men.

Setting Tires with Hot Water.—The use of hot water in place of fire for expanding tires may not be new, but it is less common than it ought to be, if we are to accept as accurate the results said to be obtained in the workshops of the Moscow-Nizhni Railroad, in Russia. There an iron tank, one-fourth filled with water, is fixed near a stationary boiler, from which a steam-pipe is led through it, capable of heating the water to 212° Fahr. Into this the tire is plunged by means of a portable crane, and, after an immersion of from ten to fifteen minutes, is taken out and immediately placed on the wheel. The allowance for shrinking—in other words, the difference between the diameter of the skeleton and that of the tire—is 0.75 millimetre to a metre. This is ascertained by gauges of great accuracy; and, if it be deviated from, the tire will either be loose after cooling, or too small to get on the wheel. When fire is used, the tire can never be heated equally or cooled equally in all parts, and, in consequence, is sure to be more or less oval in form, which is not the case when hot water is employed. The officials of the railroad named above made a comparison of the two methods, from which it appears that, during a six years' trial of fire-shrunken tires, 37 per cent. ran loose, and 5 per cent. were broken; while, during a three years' trial of water-shrunken tires, less than one per cent. ran loose, and only a single tire was broken.

Distribution of Prairie and Forest.—Many are the theories which have been offered to explain the distribution of prairie and forest. The continued existence of the prairies of the West has been attributed to the annual fires; to the nature of the soil and its underlying rock; to deficiency of rainfall; finally, to deficiency of winter rains and snow. The contrary conditions would, according to these theories, favor the production of forests. Prof. J. E. Todd, who, in the *American Naturalist*, discusses this problem with special reference to South-

western Iowa, offers a very ingenious theory, and one that certainly appears to account for the phenomena observed by him in the above-mentioned region. He finds that—1. In the hill-regions where the slopes are inclined from 5° to 10°, timber occurs mostly on the northern slopes, just south of creeks flowing east or west; it occurs a little less frequently on western slopes, east of creeks flowing north or south; 2. In the bluff-region, where the slopes are from 10° to 45°, just east of the bottom-lands of the Missouri, timber is found over most of the surface. This belt of timber-land is usually bounded on the west by the crest of the most western ridge of the bluffs, leaving the slopes facing the bottom-land bare, except when a lake, slough, or stream, comes close to the base of the bluffs, or where the bluff-side is deeply furrowed by ravines; 3. In the low alluvial valleys, timber is found along the streams, usually in narrow strips, and generally wider on the east and north banks; the rest of the bottom-land is destitute of trees and bushes. According to the author, *constancy of moisture* is the condition *sine qua non* of forest-growth; and, 1. This constancy of moisture must be in one or both the media in which the trees are to exist—the soil or the air; 2. It is plain that moisture of soil will be more constant on northern slopes than southern, the former being less exposed to the sun's heat. In the spring, and after showers, the northern slopes dry up more slowly, and, at certain degrees of humidity of the air, the moisture given off by the southern slope of a hill may be condensed by the northern. These and other like considerations may perhaps account for the timber occurring on northern slopes, while it is nearly absent from southern; 3. The fact that the prevailing winds of Southwestern Iowa in spring and summer are westerly may perhaps explain the preponderance of timber-areas on the east banks of the streams flowing south; and this, combined with the increased roughness of the surface, may also go far toward explaining the timber-belt of the bluff-region; 4. It remains to explain the distribution of timber and prairie in the alluvial valleys. Here layers of clay prevent the ready drainage of many parts; these conditions render much of the surface too wet (for trees) at all times, while other places are too wet in spring and too dry in summer. On the other hand, the occurrence of trees along the streams and on ridges along old channels may be explained partly by the inequality of surface, making the drainage of surplus water possible, so that moisture around the roots is more constant than elsewhere on the bottoms.

More about the Agricultural Ant.—While visiting Texas last summer, the Rev. H. C. McCook attentively studied the habits of the agricultural ant (*Myrmica molefaciens*). His observations are, for the most part, strongly confirmatory of the statements made by the late Dr. Lincecum; but he also adds to our knowledge of these interesting insects a number of new and interesting facts. Mr. McCook has published, in the "Proceedings of the Academy of Natural Sciences of Philadelphia," a general preliminary statement of his results, intending soon to treat the subject more fully. He carried on his observations in the vicinity of the city of Austin, where the soil is black and sticky, varying in depth from three feet to a few inches. The formicaries of the agricultural ants are commonly flat, circular clearings, hard and measurably smooth, aptly called "pavements" by Lincecum. A few of them had in the centre low mounds, a few inches in height, and two or three in diameter. The formicaries vary in width from twelve feet to two or three feet. They are invariably located in open sunlight. The process of making a clearing strongly suggested the modes of pioneers in a forest—spires of grass taking the place of trees. The chain of evidence that determines these ants to be true harvesters in as follows: 1. Workers were seen gathering seeds and carrying them into the formicaries through the central gates; 2. The same seeds were found in granaries within the opened formicaries; 3. The seeds, with outer shell removed, were found in other granaries; 4. The ants were found carrying out shells to the refuse-heaps. The author's opinion is, that these ants do not plant seeds on purpose, but that they carefully preserve on the outer margin of the clean space the growths which arise from seeds dropped accidentally. To the question

whether there is anything like a systematic direction of the labors of the ants by the queen or the major-workers, Mr. McCook replies that the queen seems to have nothing to do but to replenish the population of the community; her life is spent mostly underground. No "officers" could be seen, and each ant acts independently. The worker-majors act constantly as sentinels, and once or twice was observed what appeared to be, on their part, an effort to aid the harvesters in gathering seeds. The entrances to the interior of the formicary are circular openings or gates at the surface, connecting with tubular galleries which lead to the granaries. These granaries consist of rooms of a more or less oval shape, one above another, after the manner of floors in a house. The rooms are about half an inch in height, with hard and smooth roofs and floors. Similar rooms are employed for nurseries of the young. The rooms of each story, as also the different stories, are connected together by galleries. The author gave examples showing strong intelligence in separating white meal from arsenic, with which it had been mixed, and of the refusal of poisoned molasses.

Birds' Eggs and Birds' Nests.—There exists a curious relation between a bird's *mode of nesting* and the *color of its eggs*. The circumstance is noted in the *Bulletin of the Nuttall Ornithological Club* by Mr. J. A. Allen, who observes that nearly all birds that nest in holes, either in the ground or in trees, lay *white* eggs. As instances of this fact may be cited, the woodpeckers, kingfishers, bee-eaters, rollers, hornbills, barbets, puff-birds, trogons, toucans, parrots, paroquets, and swifts; while only occasionally are the eggs white in species which build open nests. A few exceptions are noted by the author to the rule, according to which only *white* eggs are laid in open nests; these are owls, humming-birds, and pigeons. On the other hand, in only two or three small groups of species that nidificate in holes are the eggs speckled or in any way colored. Wallace, it will be remembered, has endeavored to show that the form of nest is, as a rule, correlated to the color of the female bird: if the color is brilliant or in any way striking, the nest is concealed; and *vice versa*, if the female is inconspicuous in color, the nest is open. Mr. Allen, in the paper from which we are quoting, calls attention to the many weak points of Wallace's theory, and asserts that a more uniform correlation exists between color of eggs and style of nest than between the two members of Wallace's correlation. Mr. Allen, however, does not care to formulate a "law" upon the basis of the facts stated above, the exceptions being, as he says, too numerous to consist with the relation of cause and effect.

Subterranean Water-Courses.—It often happens, in years of great drought, that the waters of the Danube, near its source, nearly altogether disappear in the fissures and holes in the bed of the river. The proprietors of works situated farther down-stream have frequently closed these subterranean passages, to avoid losses of water. But other manufacturers, owning works on the Aach, a tributary of Lake Constance, a few miles distant from the Danube, and at an elevation some 150 metres less, contended that these holes and fissures in the bed of the Danube open into water-passages connecting with the source of the Aach; hence they applied to the courts for an injunction to prevent the stopping of these outlets. To test the truth of this theory of the Aach water-supply, 10,000 kilogrammes of common salt was thrown into the Danube at the point where it gets lost. This salt reappeared in the water of the source of the Aach. Another experiment consisted in mixing fluoresceine with the Danube-water at the same point. On October 9th, at 5 P. M., about fifty litres of this dyestuff was poured into one of the openings in the river-bed. On the morning of October 12th, the observers stationed at the source of the Aach perceived the coloration of the water, which was of an intense green. The color grew more and more intense till the evening of October 12th, and disappeared about 3 P. M. of the 13th.

A Bird-eating Trout.—A correspondent of *Land and Water* tells a well-accredited story of a trout caught in the act of swallowing a sparrow which it had seized. The trout had been kept for some time in an

open shallow well or spring, and had become very tame. In the well was a flat stone, one end of which projected above the water. On this small birds would alight to drink, and the villagers suspected that more than one of them had fallen victims to the trout's rapacity. This surmise proved to be correct, for, one day while the owner of the well was passing with some friends, a splashing in the water caused them to turn and look. There was the trout struggling hard to gulp his prey. One of the spectators fearing that the fish would be choked by the wing-feathers, thrust his hand into the water, and caught hold of them. But the trout, unwilling to surrender any part of his prize, held on resolutely, and the feathers had to be taken from him by force.

Meteorological.—In the eighth of Prof. Loomis's papers on Meteorological Phenomena, published in the *American Journal of Science* for January, with a view to determine the circumstances under which storms originate, the author takes all the instances in which the barometer fell below 29.25 inches at any station, Mount Washington and Virginia City excepted, during a period of twenty months from September, 1872, to May, 1874. The number of instances was 148, and corresponds to 44 different storms. Two-thirds of these storms had their origin north of latitude 36°, and one-half upon or very near the Rocky Mountains. Two of them came from the Pacific Ocean, three from the Gulf of Mexico, one from near Cuba; others were widely distributed in Wyoming, Dakota, Colorado, and elsewhere. The first stage in each of these storms was the development of an area several hundred miles in diameter, over which the barometer was about thirty inches, with areas of high barometer on both the east and west sides, a thousand miles distant. These areas of high barometer are one of the most important causes of the storm which succeeds. From this cause there arises a movement of air toward the central area which is relatively one of low barometer. The air thus in motion is deflected to the right by the earth's rotation, giving rise to the well-known rotary motion of air during a storm's progress; there also occurs a diminished pressure in the central portion, and an upward movement of the air. The upward-rushing air carries with it large amounts of aqueous vapor which is condensed into rain. By the condensation of the vapor, heat is liberated, causing expansion of the air, and more violent inward movement of the wind. The rainfall thus tends to increase the force and violence of the storm, and invariably occurs when the storm is at its height. Heavy rains usually occur eastward of the storm-centre—that is, eastward of the area of lowest barometer—and usually diminish when the centre has passed. The author says, "I have found no instance of violent storms which was not attended by considerable rainfall, but the rainfall is to be considered as a result, not the cause of the first movement of the wind."

It was shown, in a former article, that storms have a forward motion, which is usually a little north of east. No sooner is a storm-centre formed than it begins to change its position. The storm's movement seems, with few exceptions, to correspond with that of the atmosphere, the average annual progress of which is from west to east. Prof. Loomis says that on the west side of a storm a pressure occurs, resulting from the cause which determines the general circulation of the atmosphere, and which exists whether a storm occurs or not. A storm disturbs the atmosphere chiefly in its lower portion; in the upper portions the general atmospheric movement goes on. The depressions of the atmosphere on the west side of a storm are from these conditions filled up, so that the barometer is continually rising closely in the rear of a storm, but as continually falling as before explained, just eastward of the storm-centre. It is a matter of common observation that, when a storm-centre is passed, high barometer and clear air are close at hand. Other conditions of a storm's progress are presented, and the interesting fact developed that high barometer, east and west of a storm-area, remains unaffected by the tempest that is raging between those areas—whence Prof. Loomis infers that the air inflowing in the storm and rising at or near its centre flows outward at a considerable elevation to the areas of high barometer, having been deprived of its aqueous vapor. It thus appears that a vertical circulation is going on during a storm's progress.

Snake-Affection.—Most people will prefer knowledge at second hand of the playfulness and affection of snakes, to personal tests of the existence of such qualities. Not so a correspondent of *Land and Water*, who, having got possession of a harmless snake of the species *Natrix torquata* about twenty-eight inches in length, adopted it as a pet. This snake took great pleasure in passing in and out again and again between the fingers of its master. It was only necessary to hold the hand in the open box, when he would at once commence to glide between the fingers, always turning round sharply the instant its tail was free, and resuming its journey in the contrary direction. The process of shedding the skin is worthy of observation. The snake lies in a sluggish state for several days. The bright eyes become dull and fishy, and the skin loses its glossy smoothness. In time a slight break appears to run in the line of demarkation between the mucous membrane of the mouth and the outer skin, along the edge of the lips. In a few hours the crack appears to widen, and the skin to dry and curl over at the edges. Soon after this, in the present instance, the snake passed through a wisp of straw provided for this purpose in his box, and the skin was stripped off in one piece. The animal was now as active as a kitten, and as hungry. He quickly swallowed a fog, whose cries were heard after it had passed into the snake's stomach.

A Magnetized Spider.—In a communication to the Academy of Natural Sciences of Philadelphia, Dr. John Vansant treats of the influence of magnetism on living organisms, and describes at length one experiment with a spider, which was killed by the magnetic emanation. The magnet employed was a small steel one, of the U-shape, the legs of which were about two and one-half inches long by one-half inch wide and one-sixth inch thick, the distance between the poles being about one-quarter inch. Having noticed a small spider actively running along the arm of his chair, he brushed it off upon the carpet, where it began to run, but was somewhat impeded by the roughness of the fabric. He now slid the magnet along the carpet, following after the spider, till it was between the poles. The animal almost instantly stopped, and in a few seconds was motionless; but, at the end of two or three minutes, it began slowly to move its legs and elevate and depress its head. At the end of five minutes the spider was quite still. After the lapse of ten minutes Dr. Vansant covered both spider and magnet with a tumbler. On the expiration of two hours, he removed the glass and observed the spider with a magnifying-lens. It was apparently dead. The author states that he has killed spiders and other small animals, as worms and insects, as well as some plants, by magnetism, at various times during the past eight years, but never before succeeded in destroying the life of a spider so quickly, and without touching it frequently, though lightly, with the magnet. In the present instance he did not touch the animal at all.

Waste of the Locomotive-Whistle.—Persons residing in the country near any of the great railway lines will heartily approve any effort made toward suppressing the nuisance of locomotive-whistles. A writer in the *Railroad Gazette* remarks as follows on the *wastefulness* of this practice: "A simple toot or two," he writes, "in cases of emergency, to warn some one from the track, or as a signal for brakes, would seem to be the only legitimate use of steam in the way of whistles. And yet, of the twenty or more trains which daily pass my residence, I notice that nearly one-half make a regular practice of blowing their whistles some twenty rods at a time, and some half a dozen times within as many miles; and their safety-valves also seem to be at work most of the time. It would be interesting to know exactly what percentage of the fuel is wasted in this way. If the coal-bunks upon their tenders were made so as to let a bushel of coal drop on the track every ten miles of their progress, the waste would then become so manifest, no doubt, that it would be attended to at once. If one train can be run without the use of the safety-valve or whistle, another can be so run, with the exercise of an equal care and vigilance on the part of the engineer and fireman. This matter of waste at the safety-valve and whistle seems to rest entirely with the men upon the foot-board of the engine; and, as they prize their good standing as engineers and firemen, they should attend to it."

NOTES.

THE Department of Agriculture has received from General Charles P. Stone, now in the military service of the Khedive of Egypt, a lot of red-date seed, with which it is designed to make the experiment of growing the date-palm in the United States. General Stone, from what he has seen of the date-producing regions of Northeastern Africa, and from his observations in the Desert of the Colorado, between Carissa Creek and Fort Yuma, is inclined to believe that the greater portion of the latter region can be made productive and very valuable by the culture of this tree. The date-palm, he writes, not only does not require much water, but much water is prejudicial to it, and the climate of the Colorado Desert is strikingly similar to that of some of the best date-producing districts of Egypt.

IN a tower of the Temple of Ularo, in Kioto, Japan, is suspended the largest bell in the world. The date of its casting is unknown. It measures 24 feet in height and is 16 inches thick at the rim. It is sounded by a suspended lever of wood, used like a battering-ram, striking the bell on the outside. The Bolshoi (Giant) in Moscow, cast in the sixteenth century, and recast in 1654, was 21 feet high and 18 feet in diameter; its weight was estimated at 288,000 pounds. The metal of this bell was used in casting the present "great bell of Moscow," the *Tsar Kolokol*, 19 feet 3 inches high, and about 19 feet in diameter; estimated weight, 443,772 pounds.

THE Central Railroad of New Jersey have, at their Communipaw shops, a small gas-works for converting into illuminating gas, oil-waste and other combustible material collected along the line of road. The fuel used in the gas-furnace is the screenings from the locomotives—a material previously used only for road-ballast. The gas costs the company only 35 cents per thousand feet, and enough is produced to supply 225 burners. Its illuminating power is said to be very high.

IN the opinion of the *Lancet*, California will, before long, be supplying Europe with wines that will bear comparison with the finest vintages of the Rhine and the Moselle. A few years ago there was an exhibition at Kensington, of the wines of many countries, at which the wines from California took a very high rank. An analysis of these wines, recently published in the *Pharmaceutical Journal*, makes a very favorable exhibit for our Pacific slope vintages.

THE fourth annual report of the Buffalo Society of Natural Sciences gives evidence of a highly-creditable degree of scientific activity on the part of the members of the society; but we regret to notice that the publication of the *Bulletin* has been for the present suspended, from the want of funds to continue it. During the year 1877 the society's collections were used by the scholars of the public schools of Buffalo as a means of instruction in natural history. The number of books in the library has been considerably increased. The zoölogical specimens added to the collections during the year were numerous. The original scientific work of members of the society has afforded material for 33 memoirs, published by the Department of the Interior, and in various scientific journals. To the society is due the credit of having inaugurated a course of cheap winter evening lectures, at an admission-fee of ten cents.

THE use of "toughened" glass is not without its dangers, as we learn from the experience of a certain Prof. Ricard. He bought a child's cup of toughened glass, which was exposed to hard usage for some months, without suffering from the rough treatment. But one evening it was left, with a spoon in it, on a table, and the room was shut. Shortly afterward a noise as of a pistol-shot alarmed the whole household. On entering the room, fragments of glass were found scattered all around—the cup had exploded after the manner of a Prince Rupert drop.

A PROCESS of engraving on glass and crystal by means of electricity has been discovered by M. Gaston Planté. The process consists in covering the plate to be engraved with a concentrated solution of nitrate of potash, put in connection with one of the poles of a battery, and in tracing the design with a fine platinum point connected with the other pole. M. Planté employs a battery composed of 50 or 60 secondary elements.

IN an establishment at Oakland, California, the entrails of sheep are used for making very serviceable belting for machinery. First the entrails are cleaned and soaked for a few days in brine. The prepared material is then wound on bobbins, when it is ready for working up either into ropes or flat belts. A three-quarters-inch rope of this material is capable of bearing a strain of seven tons. The material, furthermore, is very durable—more than twice as durable as hemp.

THE directors of the Paris Exposition of 1878 intend to repeat, on a large scale, Foucault's famous pendulum-experiment, showing the rotation of the earth. The pendulum to be suspended in the Champ de Mars will be about 660 pounds in weight and 220 feet long, and will be so hung that the

points of suspension can freely move, thus permitting the pendulum to swing in one plane or nearly so. The spectator will notice that the pendulum changes its line of oscillation as regards the floor beneath, but if he understands the questions to be answered, he will know that it is the floor, and himself with it, that is carried round, while the pendulum continues to oscillate in one plane, or nearly so.

It has been observed by a French physician, De Renzi, that the paroxysms of those suffering from lockjaw are always more frequent and more violent by day than by night, and he has noticed the same fact in frogs poisoned with strychnine. He has further observed that the paroxysms are more intense when the animals are freely exposed to light than when they are kept in darkness, and that frogs poisoned by weak doses of strychnine die on being roughly shaken, but live when left in a state of complete repose. On these results M. de Renzi bases a new system of treatment for cases of lockjaw; it is as follows: The patient is shut in a perfectly dark room, and the door is opened very gently every four hours to give food and drink. The external auditory meatus are sealed with wax. Every hour (?) soup or an egg, with two spoonfuls of sherry, is given from a cup with a spout to it. A little powder of belladonna and ergot is given to appease the paroxysm. The floor should be covered with a carpet.

Books taken from circulating libraries for the use of convalescents may easily become the vehicles of contagious diseases, and it is much to be desired that some effectual method could be devised of disinfecting volumes which have been so used. Until this is done, circulating libraries would do well to caution their patrons against the danger, and to request that the books be not used where such diseases exist. In these days of cheap publications it is easy to obviate this peril by procuring for the use of the sick low-priced volumes, to be destroyed after they have been perused.

M. Schiaparelli, during the last opposition of Mars, made observations of the position of the south-polar spot, as was also done by Prof. Hall. The method adopted by the latter was to measure the angle of position of the spot from the centre of the disk. M. Schiaparelli made his measures by placing the wire of his micrometer tangent to the limb of the planet at the middle of the spot. The latitude and longitude (areographic) of the spot are:

$\theta = 29.47°$ (S.) $\quad \theta = 20.66°$ (E.)
$\lambda = 6.15°$ $\quad \lambda = 5.18°$

For 1877, Sep. 27.0 G. M. T.

The planting of trees in the streets of towns is condemned as unsanitary by a writer in the *Lancet*, on the ground that fresh air, Nature's great deodorizer, is checked in its movements by the foliage. In the narrow, tortuous lanes and pent-up courts, where the poorer part of the population live, anything that interferes with the freest possible circulation of the air must be injurious to health.

Dr. J. A. Campbell, writing in the *British Medical Journal*, favors recourse to summary proceedings in the treatment of "fasting girls," i. e., young females who, under the influence of hysteria, believe themselves to possess the miraculous power of living without food or drink. The hysterical manifestations, he says, can be overcome by the stomach-pump, "and with our present knowledge no more fasting girls should be *permitted to occur*."

In Texas camels are raised as easily as horses and cattle. The colts of the first three or four days are rather tender, and require close attention, but afterward they are hardy enough. They feed on cactus and brush, refusing all grasses. The females, with proper care, give a colt every year.

It is commonly supposed that the softer a bar of steel is, the better is it able to endure strains and shocks causing vibration. But experiments made by Mr. W. Metcalf, of Pittsburg, show in fact that hard steel suffers less from vibration than soft. Mr. Metcalf's attention was first drawn to this subject by the constant breaking of steam-hammer piston-rods. Those made of ordinary steel lasted only six months. Then lower and lower steels were tried, and broke in about five months. Once it happened that a rod of comparatively high steel was employed, which held out for over two years. This totally unexpected result led to systematic experiment which confirmed the conclusion stated above.

Of "trials of endurance" now so much in vogue, the latest is that undertaken by a Mr. Murphy, of Kern, California, who talked incessantly for twenty-four hours, with a rest of five seconds in each hour for the purpose of taking a drink of whiskey. At the conclusion of his task, Murphy fell from his chair, but whether this was the result of exhaustion or of intoxication could not be determined.

Experiments have lately been made in Germany to determine the value of the common nettle as a textile fibre. The weed having been treated in the same way as hemp, yielded a fibre as fine as silk and as strong as hemp-fibre. A considerable area of ground is now planted with the nettle in the Prussian province of Nassau.

CHARLES FREDERIC HARTT.